

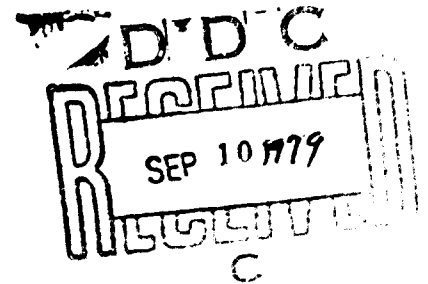
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# NC / CAM

## A DESCOM STUDY



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A COMPREHENSIVE STUDY ON THE USE AND APPLICATION OF  
NUMERICAL CONTROL/COMPUTER-AIDED MANUFACTURING  
EQUIPMENT IN DEPOT MAINTENANCE OPERATIONS AT U.S.  
ARMY DEPOT SYSTEM COMMAND (DESCOM) DEPOTS.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) In light of the fact that three separate GAO reports indicated that activities within DOD must do more to realize the full benefits of NC/CAM, the Study Group engaged in a one-year comprehensive effort to investigate, standardize, resolve, and define the many associated elements with a clear set of parameters for DESCOM activities. (U) S/C 394 668 JB		

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The study resulted in several recommendations in each of the following subject areas, with the goal of fully implementing the use of NC/CAM equipment throughout DESCOM: NC/CAM machines, Tools and fixtures, Computer hardware, Controllers, Parts programming and accessories, Interactive graphics systems, Procurement, DESCOM-wide NC management, Depot-level NC management, NC maintenance, and Training.(U)

Although the study has been completed an NC/CAM Control Center is being established at Sacramento Army Depot with the primary functions of providing advisory and consultant service to depots, and to assist them in the implementation of NC/CAM requirements.(U)

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NC/CAM

A DESCOM STUDY

JULY 1979

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## CHAPTER 1

### PROJECT EXPLANATION

#### 1-1. INTRODUCTION.

This final report for the DESCOM NC/CAM Study represents the results of a one-year comprehensive effort, and details the general findings and recommendations of the Study Group. A considerable amount of research and investigation was conducted by participants from all DESCOM installations. In addition, contacts and visitations to a number of Army, Navy, and Air Force installations, other Federal Agencies, and commercial industries, were beneficial in arriving at the final result. A wide variety of data, technical reports, correspondence, brochures, etc., and general discussions all were useful in analyzing and defining the specific courses of action to follow and resulted in the positive results of the study.

There was much coordination, and the group received excellent cooperation throughout. The enthusiasm, eagerness, and positive attitudes reflected by various personnel at each of the depots are just small indicators that the study was proper, necessary and worthwhile. The total success of the project will be measured by the future results from implementation and application of the concepts.

#### 1-2. BACKGROUND.

There has been a real need for a study of this magnitude for a number of years. Numerical Control (NC) has been in use since the early 1950's, but there has been no meaningful move to investigate, standardize, resolve, or define the many associated elements with a clear set of parameters for DESCOM activities. There was an apparent misunderstanding and lack of appreciation for the increased capabilities, value, and benefits of NC/CAM. In addition, there was no regulation or directive which clearly defined NC/CAM equipment requirements, justifications, methods, or sequences of acquisition, as well as a variety of important and critical operating conditions, techniques and standards.

The General Accounting Office (GAO) reported in three separate reports (24 September 1974, 26 June 1975, and 17 January 1979) that activities within DoD must do more to realize the full benefits of NC/CAM. It indicated that costs for maintaining, repairing, and overhauling weapons systems are enormous and are rising. It further pointed out that NC/CAM offers benefits, if managed properly, in terms of meeting mobilization requirements and achieving greater efficiencies and improved economies.

The use of NC/CAM equipment can produce meaningful and measurable benefits. The GAO reported the following advantages:

- a. Increased productivity.
- b. Reduced tool and fixture storage.
- c. Faster setup time.
- d. Reduced parts inventory.
- e. Speed of engineering changes.
- f. Better accuracy and uniformity of parts.
- g. Better Quality Control.
- h. Reduction of parts handling.
- i. Reduced skill level.

In a broad sense, a numerically controlled system is a machine that is controlled automatically by coded instructions. More precisely, it is a system in which programmed numerical values, stored in some form of input medium, are automatically read and decoded to cause a corresponding movement of the machine it is controlling. An NC/CAM system has two basic elements; the machine which does the work, and an electronic control unit which directs the machine's motions. Both operate as an integrated unit. A few NC/CAM machines operate directly from computers, but most get instructions in the form of punched tape. The applications of NC/CAM are virtually limitless. It can be applied to any operation in which a tool or workpiece is moved from one point to another and stopped, and then the work is done. Although most NC/CAM equipment is metal working, its applications include electronics manufacturing, glass making, food processing, materiel handling, drafting, woodworking, plastics and inspection, just to name a few.

Numerical control, like most technologies, is an advancing and evolutionary process. Hard-wired systems, which were universal a few years ago, have given way to minicomputers and microprocessors which are less costly and more reliable and have greater capability. Further, computer graphic systems for part design, part programming, and shop management information systems, are progressing at a fast rate and are expected to increase productivity and reduce manufacturing costs substantially.

Because of a lack of overall direction or coordination, the GAO stated that there have been varying and inadequate degrees of attention

among the service activities to NC/CAM as a productive mode of manufacturing. As a result, there is still no overall direction or guidance established. This condition prompted DESCOM to initiate and conduct its own study on the use of NC/CAM within the DESCOM complex.

1-3. PROJECT PERSONNEL.

The project was initiated on 3 April 1978, as a result of a telephone conversation between Mr. Harry Dell, DESCOM, and Lt. Col. Ancil Pressley, Comptroller, SAAD. A teletype message (041630Z, April 1978, DRSDS-PMI) (See Fig. 1-1) the following day officially tasked the Sacramento Army Depot to conduct the study. An initial task force was established, and consisted of personnel at SAAD, and points of contact at all affected depots. They are as follows:

- a. Russell E. Harris, SAAD (Project Leader)(borrowed from Directorate for Services).
- b. Bernard O. Grindle, SAAD (borrowed from Directorate for Maintenance).
- c. Elwood M. Bourtayre, SAAD (borrowed from Comptroller)(See Note 1).
- d. Roy Oliver, CCAD.
- e. Lee Williams, TEAD.
- f. Jerry Marks, ANAD, (later replaced by Shelley Sewell).
- g. James Shindle, LEAD.
- h. Edward Slimak, TOAD.
- i. Oscar Zeiders, NCAD, (later replaced by Martin Pickle).
- j. Joseph Moore, RRAD, (later replaced by Marshall Foster).
- k. Kenneth Crank, PUDA, (later replaced by Henry Musso).
- l. Don Fratangelo, SEAD, (See Note 2).
- m. Don Nieminen, SHAD, (later replaced by William Carson)(See Note 3).
- n. Dolan Reynolds, SIAD, (See Note 4).
- o. Dr. Frank J. Janza, SAAD, (See Note 5).

p. Dr. Karl E. Stoffers, SAAD, (See Note 5).

q. Steven Sasaki, SAAD, (See Note 6).

r. William Humenick, SAAD.

NOTE 1: Elwood Bourtayre left the project and resigned from Federal Service in April 1979, to pursue another career. No replacement secured.

NOTE 2: Don Fratangelo retired from Federal Service in December 1978. There was no replacement secured.

NOTE 3: William Carson dropped from the study in March 1979, due to more urgent requirements at SHAD. No replacement.

NOTE 4: Dolan Reynolds is Chief, Equipment Management Division, SIAD, and his responsibilities were such that prevented his active participation. No replacement.

NOTE 5: Dr. Frank Janza and Dr. Karl Stoffers are Professors of Electrical and Electronic Engineering at California State University, Sacramento. They provided part-time and limited full-time effort during the entire life of the project.

NOTE 6: Steven Sasaki was a summer hire in 1978 only, and provided clerical support of project documents. No replacement secured.

NOTE 7: All other personnel remained active with the project until final completion.

#### 1-4. PLAN OF ACTION.

The Study Plan of Action (See Fig. 1-2), which was officially endorsed by BG James S. Welch, Commander, US Army Depot System Command, on 10 July 1978, requested the support of all depots. It was pointed out that "the use of NC/CAM equipment could enhance the capability of each depot, while reducing the cost of operations." Further, "the goal is for full implementation of the use of NC/CAM equipment throughout DESCOM."

Once the total staffing was established, research and investigative action commenced. A wide assortment of available documents (textbooks, letters, publications, reports, directives, regulations, standards, specifications, etc.) were reviewed in order to establish and define elements and topics which were to receive comprehensive investigation. This resulted in a set of parameters and guidelines for the acquisition, use, and management of NC/CAM equipments and establishment of a regulation. A series of visits to various Government installations



(Army, Navy, and Air Force) were scheduled to observe NC operations and to secure appropriate information and ideas. They included:

- a. Anniston Army Depot, Anniston, AL
- b. Corpus Christi Army Depot, Corpus Christi, TX
- c. Tobyhanna Army Depot, Tobyhanna, PA
- d. Watervliet Arsenal, Watervliet, NY
- e. Rock Island Arsenal, Rock Island, IL
- f. Tinker Air Force Base, Oklahoma City, OK
- g. Kelly Air Force Base, San Antonio, TX
- h. Hill Air Force Base, Salt Lake City, UT
- i. Wright-Patterson Air Force Base, Dayton, OH
- j. Warner-Robbins Air Force Base, Warner-Robbins, GA
- k. McClellan Air Force Base, Sacramento, CA
- l. Naval Avionics Center, Indianapolis, IN
- m. Naval Air Rework Facility, Patuxent River, MD
- n. Naval Air Rework Facility, San Diego, CA
- o. Naval Air Rework Facility, Norfolk, VA
- p. Naval Air Rework Facility, Cherry Point, NC
- q. Naval Air Rework Facility, Pensacola, FL
- r. Naval Air Rework Facility, Alameda, CA
- s. Naval Weapons Station, Seal Beach, CA

Attendance and participation in various industry trade and tool shows, seminars and symposiums, and factory tours, also contributed to the study effort. They included:

- a. National Machine Tool Show, Chicago, IL
- b. CAD/CAM VI Conference and Show, Los Angeles, CA

- c. NC Society Meeting, Los Angeles, CA
- d. Manufacturing Management and Technology Conference, Palo Alto, CA
- e. Group Technology Seminar, Arlington, TX
- f. Otis Manufacturing Company, Carrollton, TX
- g. Hewlett-Packard, Palo Alto, CA

Interest in the study was evident, and the group was requested to provide briefings at various conferences and workshops, as follows:

- a. Director for Maintenance Conference, Alta, UT
- b. DESCOM Commanders' Conference, Sacramento, CA
- c. DoD NC/CAM Workshop, Memphis, TN
- d. DoD Conference, Pentagon, Washington, D.C.
- e. DESCOM NC/CAM Conference, Sacramento, CA
- f. NC/CAM IPR Conference, Corpus Christi, TX
- g. Industrial Robot Conference, Hill Air Force Base, UT

After research was performed and data analyzed, a list of 26 elements was defined, which formed the basis for this final report. They cover a wide spectrum, and consist of topics that must be considered when establishing or expanding an NC/CAM operation. These elements are:

- |                      |                         |
|----------------------|-------------------------|
| a. NC Hardware       | i. Controllers          |
| b. Tooling           | j. Interactive Graphics |
| c. Spare Parts       | k. Adaptive Controls    |
| d. NC Software       | l. Authorization        |
| e. Parts Programming | m. Funding              |
| f. Post Processors   | n. Acquisition          |
| g. Data Interchange  | o. Site Preparation     |
| h. Computers         | p. Specifications       |

- |                            |                                       |
|----------------------------|---------------------------------------|
| q. Maintenance             | v. Computer-Aided Manufacturing (CAM) |
| r. Workload Mix            | w. Computer-Aided Design (CAD)        |
| s. Utilization             | x. Economics                          |
| t. Skills                  | y. Other Projected Uses               |
| u. Effects on Organization | z. Training                           |

Details pertaining to these elements are discussed in Appendix A (Hardware), Appendix B (Software), Appendix C (Intelligent Hardware), Appendix D (Procurement), Appendix E (Work-Mix Analysis), Appendix F (Day-to-Day Operation), Appendix G (Skills, Training, and Impact on Organizations), and Appendix H (Overall Concepts).

The plan of action also contained a Milestone Chart (See Fig. 1-2). Progress toward final completion remained on schedule throughout the entire study period. The ability to achieve and maintain project actions on-schedule must be reflected by the type and style of participating personnel. They were eager, dedicated, and enthusiastic toward reaching the final conclusion of the project. In addition, the total support and cooperation provided by the many individuals contacted during the life of the study, was exceptional.

#### 1-5. CONCLUSION.

The staff assigned to conduct this comprehensive study, together with all of the points of contact at each depot, were very pleased to have had the opportunity to participate. The challenge presented by the many aspects of the study and the results obtained, were worth the effort. It is the goal of the group that these results will benefit all of DESCOM, by paving a new direction, whereby improved productivity will occur with a significant reduction in operating costs. The "road map" has been established and the depots now have a "green light" to move forward. The NC/CAM Study Group is prepared to provide additional service, as advisors; as consultants; or even to perform a new independent investigation if appropriate and if requested.

The details explained in the following chapters, and appendices, should help to highlight and define the parameters, guidelines, conditions, controls, and operating criteria for the use of NC/CAM equipment at all installations within the US Army Depot System Command.

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FM CDRDESCOM CHAMBERSBURG PA//DRSDS-PHI//

TO RUWFWA/CDRSAAD SACRAMENTO CA//SDSSA//

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SUBJ NUMERICAL CONTROL EQUIPMENT (NEG)

A. FONECON, 3 APR 78, BETWEEN MR. DELL, THIS COMMAND, AND LTC PRESSLEY, SDSSA-C, AND MR. NAFFZIGER, SDSSA-MPE.

1. IAW REFERENCE, SAAD IS TASKED TO CONDUCT A STUDY TO DETERMINE ADDITIONAL REQUIREMENTS AND JUSTIFICATION FOR NUMERICAL CONTROL EQUIPMENT WITHIN DEPOT SYSTEM COMMAND. THE STUDY SHOULD INCLUDE THE FEASIBILITY OF INNER-DEPOT NC TAPE TRANSMISSION; NC TAPE CODE STANDARDIZATION; COMPUTER ASSIST PART PROGRAMMING; COMPUTER ASSIST PART PROGRAMMING LANGUAGE AND DIRECT COMPUTER CONTROL.

2. REQUEST SAAD SUBMIT PLAN TO DRSDS-PHI AS SOON AS PRACTICAL.

3. COORDINATE AS NECESSARY WITH OTHER DEPOTS.

BT

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NNNN

Figure 1-1

001111NF



DEPARTMENT OF THE ARMY  
US ARMY DEPOT SYSTEM COMMAND  
CHAMBERSBURG, PENNSYLVANIA 17201

10 JUL 1978

IN REPLY REFER TO  
DRSDS-CG

SUBJECT: Numerical Control/Computer-Aided Manufacturing

SEE DISTRIBUTION

1. Reference is made to message 041630Z Apr 78, DRSDS-PMI, Subject: Numerical Control Equipment (NCE).
2. Attached as Inclosure 1 is a copy of the Plan of Action for an in-depth study to identify and evaluate the use of Numerical Control/Computer-Aided Manufacturing (NC/CAM) equipment within DESCOM. Sacramento Army Depot (SAAD) has been tasked to conduct the study and will require participation and input from each depot that has a maintenance mission.
3. I fully indorse this study, and your support is required to assure success. The use of NC/CAM equipment could enhance the capability of each depot, while reducing the cost of operations. The goal is for full implementation of the use of NC/CAM equipment throughout DESCOM.

1 Incl  
as

  
JAMES S. HELLER  
Brigadier General, USA  
Commanding

DISTRIBUTION:

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Cdr, Sierra Army Depot  
Cdr, Tobyhanna Army Depot  
Cdr, Tooele Army Depot

(Info copies to each Dir/Maint)

Figure 1-2

19 June 1978

## STAFF STUDY

## PLAN OF ACTION

1. STUDY TITLE: Numerical Control (NC) and Computer Aided Manufacturing (CAN).
2. PURPOSE: To conduct an in-depth study to clarify and define the conditions, parameters, controls, and operating criteria of NC equipment; to develop a method and system to enable DESCON depots to become aware of the capabilities and benefits of NC and CAN; to identify functions, operations and tasks at DESCON depots which are being performed with conventional methods, that should be done with NC; to assist in the acquisition and establishment of effective NC/CAN facilities; and to conduct follow-on evaluations.
3. STUDY SPONSOR: U.S. Army Depot System Command (DESCON).
4. STUDY AGENCY: Sacramento Army Depot (SAAD).
5. AUTHORITY: Message #4163#2 Apr 78, DRSDS-PMI (Atch 1).
6. SCOPE: This study applies to all depots within DESCON.
7. BACKGROUND: Numerical Control machines have been in use for several years, but there has been no apparent move to investigate, standardize, resolve, or define the many associated elements with a clear set of parameters. There is an apparent misunderstanding and lack of appreciation for the increased capabilities, value, and benefits of NC and CAN within DESCON activities. In addition, there is no current regulation or directive which clearly defines NC equipment requirements, justifications, methods, or sequences of acquisition, as well as a variety of important and critical operating conditions, techniques and standards.
8. STATEMENT OF THE PROBLEM:
  - a. To investigate and determine the requirements, standards, justifications, methods, and sequences for acquiring NC and CAN equipment.
  - b. To research, review, and define:
    - (1) NC Hardware and Software
    - (2) Parts Programming Languages
    - (3) Tooling requirements and coding
    - (4) Preventive and repair maintenance needs
    - (5) Skills and training requirements

(6) Methods of approval and funding

(7) Machine utilization

(8) Workload mix

(9) Computer-Aided Manufacturing

c. To review, analyze and define Computer Assist Part Programming and Direct Computer Control.

d. To investigate and determine the method for standardization of NC Tape Codes and language characteristics, and how they can be applied at DESCON depots.

e. To review and determine the method for inter-depot transmission or interchange of NC Tapes and Data Packages, and how they will be cataloged and controlled.

f. To investigate and identify the type and location of a centralized control center for NC acquisition and use.

g. To research and develop the operating criteria, characteristics, procedures, and regulatory controls.

9. ASSUMPTIONS:

a. That the use of NC/CAM equipment is feasible and possible at all DESCON depots that have a maintenance mission.

b. That standardization of NC Hardware and Software is desirable and possible.

10. OBJECTIVES:

a. Develop and enforce a policy for standardizing both NC Hardware and Software.

b. Improve the system for identifying and describing functions, operations, and tasks to be performed with NC machines, and provide guidance and criteria for defining and evaluating workload mix.

c. Define and establish a DESCON NC/CAM Control Center with total responsibility for the implementation and control over the NC Program, to include the authorization, funding, and acquisition of NC Hardware, Software, and all associated ancillary equipment and programs.

d. Improve the planning for NC machine purchases, by developing guidelines for NC/CAM as a total production system (i.e., computer support, organizational responsibility, trained personnel, spare parts, prompt installation, etc.), and the preparation of accurate and meaningful justifications.

e. Establish a centralized DESCON inventory of NC machine spare parts, to include policy guidance for standardization and elimination of duplicate parts, and establish a simple, effective and timely method for requisitioning parts from the inventory when required to repair and/or refurbish existing NC machines.

f. Clarify and define the policies on machine utilization and reserve capacity of NC equipment to obtain maximum use of such equipment.

g. Improve the management and control of Numerical Control. Provide specific guidance for:

(1) Personnel training on NC equipment (Hardware and Software)

(2) Detailed criteria and procedures, including cost comparisons

(3) Adequate and effective preventive and repair maintenance programs

(4) Better organized system for exchanging work between similar activities.

(5) A more active campaign of informing and educating personnel and managers on the capabilities and benefits of NC.

h. Provide guidance for reducing national inventories of selected repair parts through the use of NC equipment, and of exchanging NC Data Packages.

i. Establish uniform guidelines on developing post benefit analyses to more accurately disclose the true savings and costs of NC equipment.

j. Analyze the contribution and use of computers, controllers, and computer-aided manufacturing, and define conditions for application at DESCON depots.

k. Examine, correct, and/or develop regulations, and procedures regarding NC equipment acquisition, maintenance, utilization, and personnel training.

l. Identify and define skill levels, to include operator, programmer, coordinator, maintenance personnel, and tooling specialists. Also, define the degree and type of training required for each skill.

11. TINEFRAME: The study is expected to be completed by the end of FY-79.

12. CONSTRAINTS: There are no known constraints at this time.

13. REPORTS AND FINDINGS:

a. Weekly progress reports will be provided to DESCON, ATTN: DRSDS-PMI (Harry Dell), via telephone. Also, local command will receive concurrent reports.



b. Briefing sessions will be given on a periodic basis, with a formal in-process briefing scheduled during the 4th DESCOM Directors for Maintenance Conference (17-21 July 1978, Alta, Utah) and the 5th DESCOM Depot Commanders' Conference (1-3 August 1978, Sacramento, California). Additional briefing sessions will be provided as requested.

c. Final report, with recommendations, will be documented and submitted to DESCOM, for review, approval, implementation, and other actions as required.

**14. STUDY PERSONNEL (POINTS OF CONTACT):**

- a. Russell Harris, GS-11, Project Leader, SAAD
- b. Bernard Grindle, GS-9, SAAD
- c. Elwood Bourtayre, GS-9, SAAD
- d. Roy Oliver, GS-12, CCAD (Corpus Christi Army Depot)
- e. Lee Williams, GS-9, TEAD (Tooele Army Depot)
- f. Jerry Marks, GS-12, ANAD (Anniston Army Depot)
- g. James Shindle, GS-10, LEAD (Letterkenny Army Depot)
- h. Edward Slimak, GS-10, TOAD (Tobyhanna Army Depot)
- i. Oscar Zeiders, GS-11, NCAD (New Cumberland Army Depot) *Martin P. Sahel*
- j. Joseph Moore, GS-11, RRAD (Red River Army Depot) — *Marshall Foster*
- k. Kenny Crank, GS-12, PADA (Pueblo Army Depot Activity)

**15. STUDY METHODOLOGY:**

a. Make initial contact with all DESCOM depots. Secure name, address, and telephone numbers of Points of Contact (POC) at each depot. (This has been accomplished).

b. Study team members will research and review available documents (textbooks, publications, letters, reports, etc.) in order to establish and define elements and topics which will require comprehensive investigative action.

c. Team members will visit selected installations in order to secure information.

d. POC's will provide specific data regarding Numerical Control operations at their particular installations, i.e., inventory of equipment, procedures, techniques, etc. (This has been accomplished.)

e. POC's may be required to travel to SAAD to assist in evaluating specific data, and to provide assistance and investigative research and evaluation.

- f. The study team will review, analyze, and catalog all factual data. Discuss and define problems and causes.
- g. The study team will conduct in-depth research and analyses of specific program elements and provide recommendations for accomplishment.
- h. Results will be reviewed, consolidated, and specific guidelines will be developed.
- i. The study team will visit each DESCOM Depot that has a Maintenance mission. Observe and evaluate operations, and tasks, and identify those that could be performed effectively using NC/CAM techniques and equipment.
- j. The study team will determine and identify the specific items of NC/CAM equipment (and any associated equipment) which should be secured by the depot to perform the appropriate tasks or operations.
- k. Results of all findings will be documented and the final study report, with recommendations and actions taken, will be submitted through command channels for review, approval, and final implementation.
- l. Periodic briefings of progress actions will be conducted with appropriate personnel at depot and DESCOM levels. Final briefing will be conducted at Command Headquarters.

16. ATTACHMENTS:

- a. Message 041630Z Apr 78, DRSDS-PMI
- b. Milestone Chart



RUSSELL E. HARRIS  
Project Leader  
NC/CAM Study Group

CONCURRENCE:

  
ANCIL R. PRESSLEY, LTC, CE, Comptroller  
JOHN E. NUNNELLY, COL, FA, Commanding

# MILESTONE CHART

1978 MAY JUN JUL AUG SEP OCT NOV DEC 1979 JAN FEB MAR APR MAY JUN

CONTACT DEPOTS  
FOR POINT OF CONTACT

PLAN OF ACTION  
BRIEFING & APPROVAL

SELECTED VISITATION

BRIEFING AT  
DIR/MAINT CONFERENCE

RESEARCH & EVALUATE  
DATA

BRIEFING AT DEPOT  
COMMANDERS' CONFERENCE

INVESTIGATE & DEVELOP  
SPECIFIC GUIDELINES

VISIT DESCOM DEPOTS.  
DETERMINE MC OPERATIONS  
& EQUIPMENT

DOCUMENT & PREPARE  
FINAL REPORT

PRESENT FINAL BRIEFING  
FOR APPROVAL

## Chapter 2

### SUMMARY OF OBJECTIVES

#### 2-1. INTRODUCTION.

The accomplishment of any study must be predicated upon certain goals or objectives. The final result, and the final evaluation against these objectives, will dictate how successful the particular study was, and if all requirements or conditions were met. In short, it becomes a "report card," for the project.

The NC/CAM study contained twelve (12) objectives. These were specifically defined in the original Plan of Action, dated 19 June 1978. A complete appraisal of these objectives is included within the various appendices, where detailed explanations are provided for specific elements and topics. The following is a summary of the results of each objective, and its accomplishment.

#### 2-2. SUMMARY RESULTS.

All of the objectives were met within the limits of present day procedures, and capabilities existing at the depots. Most of the objectives were specific to actual conditions, and were answered explicitly. Others were found to be interdependent, and thus required some restatement of existing concepts, procedures, or solutions. The objectives are defined as follows:

a. Develop and enforce a policy for standardizing NC Hardware and Software. It is not possible to establish a true standardization policy. It is more proper to establish a system of commonality. Standardization does remove many of the time-consuming problems and reduces the cost encountered in manufacturing. However there is a limit as to how far standardization can be applied, let alone, be implemented. Within the depot system, specific NC machines for a given depot must be determined based on the mission and the results of a Workload Mix Analysis. Although the same machine is not applicable to every depot, it can be used to provide a common support to a similar mission. In tooling, the need for commonality, not standardization, is recommended for the NC machine tool spindles. They should have the same taper. This would further provide commonality of tool changers. In the Software area, there is commonality among features of Parts Programming languages, Controllers, and Intelligent Terminals. For further details, see Appendices A, B, and C.

b. Improve the system for identifying and describing functions, operations, and tasks to be performed with NC machines and provide guidance and criteria for defining and evaluating Workload Mix. An effective system has been developed, and is triggered by performing an estimate for input to the Work-Mix Analysis program. This program, which has been developed by LSSA, will provide meaningful, and measurable results, which can help to define workload conditions, machine loading, and evaluation of process and functions. For complete detailed explanation, see Appendix E.

c. Define and establish a DESCOM NC/CAM Control Center with total responsibility for the implementation and control over the NC program, to include authorization, funding, and acquisition of NC Hardware, Software, and all associated and ancillary equipment and programs. The establishment of such a control center is not only feasible, but necessary. The center can be used to control the acquisition and authority, but also to provide beneficial support to all depots and identifying new systems and techniques, as well as providing support services. The DESCOM NC/CAM Coordinator should be in charge. One problem not identified is where should the center be located? A more central geographic location would be in order, but the final decision must be made by DESCOM Command personnel. One possible solution is to use the existing NC/CAM Study Group as the nucleus for the control center, with location at Sacramento Army Depot.

d. Improve the planning for NC Machine purchasing by developing guidelines for NC/CAM as a total production system (i.e., computer support, or organizational responsibility, trained personnel, spare parts, installation, etc.), and the preparation of meaningful justifications. A workable system has been developed. It is a result of the Work-Mix Analysis Program, and will help to identify what types of NC machines to purchase, as well as the type and style of support services needed. For further details, see Appendix E.

e. Establish a centralized DESCOM inventory of NC machine spare parts, to include policy guidance for standardization and elimination of duplicate parts, and establish a simple, effective and timely method for requisitioning parts from the inventory when required to repair and/or refurbish existing NC machines. It is not possible to establish and operate a centralized inventory of machine spare parts. Reason being, that due to varied missions and workloads at the depots there will not be identical machines throughout DESCOM. However, a Spare Parts Kit of high mortality items for a given machine at a given depot is desirable and necessary to reduce costly delays in machine down-time. An inventory of low mortality, common purpose items, could be centrally located to serve many depots if appropriate. See Appendix F for details.

f. Clarify and define the policies on machine utilization and reserve capacity of NC equipment to obtain maximum use of such equipment. Machine utilization must be measured and maintained. Management must have accurate and timely data on the equipment to exercise effective control. Because productivity concerns more than actuating the power switch, some other method of utilization has to be developed. Such a system has been established and will provide an effective measurement of a variety of conditions, all pertinent to the use of a machine. Eventually, the Work-Mix Analysis Program will provide a report output, based on evaluation and operational times for each part made. In the interim, a manually operated, six-position switch/time meter can help to identify valuable and accurate utilization data, including; set-up, tape run, no operator, no material, corrective maintenance, and no tape. Kelly AFB established such a device, and its cost is approximately \$700 to build. See Appendix F.

g. Improve the management and control of Numerical Control. Provide specific guidance for:

(1) Personnel training on NC equipment (Hardware and Software). A number of training requirements were determined and provided to AMETA. It also included the number of participants from each depot. AMETA used the data for input to their FY 80 budget. Also, during implementation at each depot, additional training requirements were identified, which are to be secured from vendors, as well as those to be conducted in-house. Included in these plans were operators, NC Coordinators, NC Part Programmers, Maintenance Personnel, Managers, Administrators, and others. For more detailed explanation, see Appendix G.

(2) Detailed criteria and procedures including cost comparison. Improved management and control of NC/CAM will occur. Specific guidance is included in the draft DESCOR regulation: (Management of Numerical Control/Computer-Aided Manufacturing Industrial Plant Equipment). Earlier attempts were made to utilize existing criteria and procedures developed by the Services and to modify them for use at the depots. This approach was partly successful, but will be replaced with the more direct approach resulting from the computer program developed by LSSA. A comparison of costs is just one entity from the Work-Mix Analysis Program that will aid managers in controlling and utilizing their program data for effective decisions. A comparison of cost data between NC and conventional machines will be a continuing effort. For further details, refer to Appendix E.

(3) Adequate and effective Preventive and Repair Maintenance Programs. A definite Preventive Maintenance (PM) and Repair Maintenance (RM) Program has been established. PM instructions are placed on the

NC/CAM machines to advise maintenance personnel of requirements to be satisfied on a scheduled time-phase basis. Operator maintenance is another form of PM, and should be accomplished as indicated. Corpus Christi Army Depot has developed and simplified PM instruction manuals. A signed and dated entry guarantees control on maintenance requirements and conditions. A similar system would be advantageous to all depots. It is important that all PM schedules be established and maintained. For further details, see Appendix F.

(4) Better organized system for exchanging work between similar activities. Such a system will be available after implementation of the Work-Mix Analysis Program. Information from the program will help to identify which depot programmed and manufactured a given item (by part drawing number) previously. Thus, a saving in re-programming, set-up and fixture fabrication time can be achieved. However, until the Data Link Network is satisfied and established between depots, the system will have to rely upon a copy of program summaries mailed from each depot. Even so, it should greatly assist in identifying parts for re-manufacture. For further details, see Appendix E.

(5) A more active campaign of informing and educating personnel and managers of the capabilities and benefits of NC. Depot personnel have received first-hand guidance and information primarily by visits of study team personnel. In addition, a series of training courses and seminars were identified, many being offered by AMETA. One specific plan will result after each depot has assigned and implemented an NC Coordinator system. Knowledge and information secured will be conveyed to managers and other operating personnel at each depot. This will be a continuing program and is defined in the draft DESCOR Regulation. For further details, see Appendix G.

h. Provide guidance for reducing national inventories of selected repair parts through the use of NC equipment, and of exchanging NC data packages. The complexity of such a program, and the involvement of so many different Item Managers, will make the action difficult to achieve. From a concept point of view, it is entirely feasible but the accomplishment might be expensive to complete, unless individual Item Managers agree to comply and operate on a demand type basis. It is a well known fact that stockage of parts is expensive but stockage of a part program is less expensive. It is just a matter of attitude and agreement. Group Technology is very applicable to this problem. One possible alternative is the output of the Work-Mix Analysis Program which will identify repeated results being made at each location, and in what quantities. Through this system, exchange of data requirements (not data packages) can be achieved while also reducing actual inventories. For more information, see Appendix E.

i. Establish uniform guidelines on developing post benefit analyses to more accurately disclose true savings and cost of NC equipment. Specific guidelines have been established and detailed requirements for performing post-benefit analyses, and they are included in Appendix F. It is important to perform this analysis in order to provide a more accurate indicator of progress on operations, as well as processes, and application of time standards. The results will help to identify a better "Return on Investment."

j. Analyze the contribution and use of computers, controllers, and computer-aided manufacturing, and define the conditions for application at DESCOM depots. Computers have made NC/CAM a beneficial reality. The further advent of minicomputers, microprocessors, etc., have continually added versatility and capability in manufacturing operations. All have tremendous application at the depots, and the specifics are explained in Appendices D, C, F, and H.

k. Examine, correct, and/or develop regulations, and procedures regarding NC equipment acquisition, maintenance, utilization, and personnel training. A number of DoD, DA, DARCOM, and DESCOM regulations were researched. Many contained requirements which are applicable, and which will still be followed. In addition, other service regulations, like the Air Force (AFLC Reg 66-50), covered every aspect of NC equipments. The comprehensive efforts have greatly assisted in results displayed in each of the appendices. It also was instrumental in the development of the draft DESCOM regulation. This regulation will govern the management and use of NC/CAM equipment within DESCOM depot activities. Where applicable, recommendations for changing existing regulations has occurred. As example, a specific request was submitted to change AR 235-5 and DoD Directive 4100.15 and DoD Instruction 4100.33, to cover the revised "NEW START" and "EXPANSION" requirements in the new OMB Circular A-76, which was formally published on 29 March 1979. Other changes will be submitted when appropriate. Also, input was furnished to DoD for expansion of DoD Directive 4275.5 to include the requirements of NC/CAM under the requirements of "Industrial Resources."

### 2-3. CONCLUSION.

A comprehensive review of objectives, indicates that positive and meaningful results have been achieved through the NC/CAM study. Although many concepts and ideas have been presented to the depots, and assistance provided as a triggering effect, the full range of implementation is still to come. Each depot has the necessary data and knowledge to help initiate and/or expand their NC/CAM capability. The final benefit will not be evident until specific equipment has been acquired; personnel assigned; programs written; and corresponding savings generated and reported as a normal operational factor. At that time, it can truthfully be stated that the objectives of the study have been met and results completely implemented.



## Chapter 3

### IMPLEMENTATION

#### 3-1. INTRODUCTION.

A very important part of the study program was to make an early start on the implementation of the recommendations resulting from findings to date of the NC Study Group and the personnel from the depots assigned to assist in the study. The implementation started in April 1979 with advance teams visiting all of the depots for acquiring work-mix data. This was followed by team visits in May 1979 for further implementation where the results of the work-mix analysis and the total study were utilized.

The teams were carefully selected so that each had highly experienced members in machine shop operation, tooling, production and programming. A total of three visitation teams, of three members each, were selected from all the participants in the study. The teams provided an immediate and effective method of imparting the results of the NC/CAM Study and related current information to those depot employees responsible for the purchase and application of machine tools. Direct formal presentations and informal discussion with management and shop personnel proved to be invaluable in covering and proving the benefits of NC/CAM.

The assigned tasks that were carried out successfully by the teams for each depot visited were as follows:

(1) To inform key depot personnel responsible for NC and conventional machinery and related areas -- management, manufacturing, etc. -- of the results of the work-mix analysis conducted by the teams in April 1979, and to convey the fact that it clearly showed:

(a) A sizeable reduction of manhours through the use of NC machines, and;

(b) A projected yearly savings from the computer directed Productivity Increase Ratio (PIR, conventional machine manhours/NC machine manhours).

(2) To make specific recommendations for the purchase, installation and operation of NC hardware and software as substantiated by the research and work-mix results and the observations made at the subject depot.

(3) To impart the findings of the study which included funding, tooling, training, CAD, CAM, etc.

(4) To answer questions and exchange information.

### 3.2. IMPLEMENTATION RESULTS.

The details of the visits by the teams are assembled at the end of this chapter and are separate formal reports of implementation. Included are some informal letter reports and memoranda. These reports act as an overview and record of the NC machine needs of the depots, the findings of the teams, their recommendations, the questions raised, and the personnel contacted who are responsible for implementation and operation. These records stand alone and contain the recommendations, problems and NC operations particular to each depot.

The teams and their members are presented for a record of their structure and the expertise involved. Also, given are the depots visited:

a. Team I:

Bernard Grindle - SAAD (Team Chief)  
Henry Musso - PUDA  
Ray Soden - SAAD  
Shelley Sewell - ANAD

During May 1979, they visited Tobyhanna Army Depot (TOAD), New Cumberland Army Depot (NCAD) and Letterkenny Army Depot (LEAD).

b. Team II:

Roy Oliver - CCAD (Team Chief)  
William Humenick - SAAD  
Matthew Wisniewski - TOAD  
Edward Slimak - TOAD

They visited Anniston Army Depot (ANAD), Red River Army Depot (RRAD), and Savannah Army Depot (SADA).

c. Team III:

James Schindle - LEAD (Team Chief)  
Martin Pickle - NCAD  
Marshall Foster - RRAD

They visited Tooele Army Depot (TEAD), Corpus Christi Army Depot (CCAD), and Pueblo Army Depot (PUDA).

d. Overall team. The Sacramento Army Depot (SAAD) was used as the test bed for all three of the visitation teams. The teams assembled at

SAAD from 2-4 May 1979 for prebriefings on the findings to date on the NC/CAM Study, also they were indoctrinated on the plan of action for their scheduled implementation visits to the depots.

The machine shops at SAAD were visited by the teams as a test case, thus SAAD became the first depot evaluated for implementation. This provided additional materials for use by the visitation teams and information to refine their procedures.

e. Implementation for Mainz Army Depot, Germany (MZAD). MZAD is controlled by other regulations by DESCOM for NC/CAM. Namely, that the operating contractor is responsible for developing NC/CAM requirements for MZAD. See included TWX (see Fig. 3-1).

### 3-3. FORMAL REPORTS.

The results of each depot visitation are explained in the following formal reports, and Figs. 3-2, 3-3 and 3-4:

- a. Sacramento Army Depot, 7 May 1979.
- b. Corpus Christi Army Depot, 16 May 1979.
- c. Anniston Army Depot, 17 May 1979.
- d. Letterkenny Army Depot, 17 May 1979.
- e. Pueblo Army Depot Activity, 21 May 1979.
- f. Red River Army Depot, 23 May 1979.
- g. New Cumberland Army Depot, 24 May 1979.
- h. Tooele Army Depot, 25 May 1979.
- i. Savanna Army Depot Activity, 29 May 1979.
- j. Tobyhanna Army Depot, 30 May 1979.

### 3-4. SUMMARY AND CONCLUSIONS.

The implementation program was carried out as scheduled and successfully fulfilled its mission. The cost benefits of NC/CAM were conveyed and substantiated by the teams.

Overall and individual depot implementation problems and related topics require the reading of the attached visitation reports. It is sufficient to state that the implementation program was started early and has been instrumental in promoting the NC/CAM programs for the depots.

Depots are now well informed on their NC/CAM needs from the results of the NC Study that were conveyed to cognizant people well in advance of the final report.

One general remark conveyed by the depots was the need to have continuing support in the form of consultants and advisors for a limited period. This will enable the depots to accomplish full implementation of all parameters, including the application and use of the Work-Mix Analysis program.



**DEPARTMENT OF THE ARMY**  
**SACRAMENTO ARMY DEPOT**  
**SACRAMENTO, CALIFORNIA 95813**

**SDSSA-C**

**7 May 1979**

**SUBJECT: NC/CAM Study - Implementation at Sacramento Army Depot**

1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at Sacramento Army Depot during the period of 2 - 4 May 1979. The implementing team consisted of:

Russell Harris - SAAD - Project Leader  
Bernard Grindle - SAAD  
William Humenick - SAAD  
Ramon Soden - SAAD  
Shelly Sewell - ANAD  
Roy Oliver - CCAD  
James Shindle - LEAD  
Martin Pickle - NCAD  
Marshall Foster - RRAD  
Henry Musso - PUDA  
Edward Slimak - TOAD  
Mathew Wisniewski - TOAD

2. Directorate for Maintenance personnel attending the initial pre-briefing session on 2 May 1979 were:

Arthur Weaver - Deputy Director for Maintenance  
Ted Meyers - Chief, Shops Division  
Al Burdick - Chief, Production Engineering Division  
Homer Chance - Actg Chief, Production, Planning & Control Division  
William Bauman - Chief, Electro-Optics Branch  
Ray De Jarnatt - Chief, Mech & Spec Support Branch  
Emory Goodman - Actg Foreman, Metalworking Shop  
David Whiting - Foreman, Sheetmetal Shops

3. The pre-briefing, consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at Sacramento

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Army Depot. The presentation was well received and a question and answer session concluded the pre-briefing. A tour of the Maintenance Shops was scheduled after lunch, so that team members could observe operations and equipment.

4. The remainder of the week was devoted to discussions with various personnel in Shops and Production Engineering Division. Specific details and clarification of topics were provided. The following is a resume of discussions:

a. Shops personnel appeared to be apprehensive about NC/CAM. They needed more information, and explanations were provided. The study team suggested the use of films and other technical data, which can be secured from various manufacturers and vendors. These should be shown to all shop personnel, as well as other depot personnel. Also, use the services of AMETA to help educate employees. The shop indicated that they are interested in equipment brochures and articles.

b. The sample parts, that were originally evaluated by the advance Workload Mix Team, were discussed. Shops Foreman indicated that the manhour and processing estimates were very valid and very favorable to SAAD. They indicated that the Workload Mix Evaluation procedure was a realistic and meaningful method, and they liked the results. It was very acceptable to them.

c. Concern was expressed over the lack of an adequate pay differential for NC operators, NC programmers, and Maintenance personnel. It was indicated that there is no way to effectively recruit qualified people for these skills, and to retain them. The study team indicated that a DoD study is currently underway to determine and identify a Standard Series, Job Description, and Grade Levels. The study is being conducted by the Air Force and the results should be available to all agencies.

d. A question was addressed regarding the method to identify and support repeat work. One solution was to place the program tape in the Engineering package for retention and issue on subsequent work orders. However, a better system for identification will be the new computer program on Workload Mix Evaluation, currently being written by LSSA. One element of output will indicate how many times the item has repeated, and identified by specific PCN and quantity. It will also indicate whether a tape was prepared, or if the program is contained in the memory of the mini-computers.

e. Much concern was expressed about lack of coordination and distribution of information. It was indicated that some information about NC/CAM had been available but not conveyed to all affected personnel. One suggestion is to establish an NC/CAM Committee with membership from all segments of the organization. They can evaluate needs and collectively make decisions on equipment,

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workloading, etc., as well as exchange information. The relationship between Engineering and Shops must be close and cohesive. Also, the same working relationship should be given to Equipment Management Division. The assigned NC Coordinator must be allowed freedom to provide greater support, clarification, and coordination, and he should be assigned to a staff element.

f. Concern was indicated relative to utilization of an NC Machine Tool. It was indicated that because of its capability it would be the target for constant observation by top management, and especially during briefings & tours. There will be various load conditions, and as such, a given NC machine may not be in operation 100% of each day. Measurement of utilization must be done over an extended period of time. The new computer program will provide specific information on how much, and what type of utilization, was achieved.

g. There is a need for trained personnel. It must be determined and accomplished in advance. The needs for both on-depot and off-depot training must be established. Some training can be secured from a manufacturer, while other training can be acquired from AMETA and ALMC. A continuous training program by local procedures is beneficial.

h. A question was asked if the programmer for the Punch Press (now being installed) would also program the NC Milling Machine (soon to be installed). The answer is yes, due to a lack of staffing. Again, training must be done in advance. One possible interim suggestion made by the study team was to use the programmers in ATE Branch to provide a possible start to the planned programming element. For the long range, it is best to use people who have a better working knowledge of shops machining operations and materials. Machinists and/ or engineering draftsmen can be effectively converted as programmers. The programming element should be staffed to Production Engineering Division.

i. Programming includes the ability to understand and use the variety of languages that will be available with each machine acquired. A decision must be made as to using a common programming language or different machine language. As more machines are added, it is recommended that a common language be established with a Post Processor, or translator, for individual machine languages.

j. The following specific topics were discussed:

(1) Authorization. NC/CAM is DMPE, not ADPE. Letter of clarification secured from DARCOM. Change in AR 235-5 is forthcoming. OMB Circular A-76 issued 29 March 1979, change "NEW START" to be a new function only. Equipment

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to be defined as "EXPANSION" with higher dollar thresholds. An Economic Analysis (AR 11-28) is not required if a DD Form 1106 is used for replacement of equipment. The EA has to be validated by the Comptroller. Equipment needs must be pre-positioned in the DMPE 5 year program.

(2) Funding. O&MA was changed to PA Funds. This was for authority but funds were not transferred, nor were they in original budget or appropriation act. QRIP program is being increased. New threshold is \$100,000, and may be the avenue for some approved acquisitions. Be sure that money requirements are submitted in budget program to cover equipment needs in DMPE.

(3) TDA. DMPE approval is tentative TDA authority, and requisition and/or procurement can be initiated. The item of equipment must be submitted in the next update of the TDA.

(4) DIPEC. Screening by DIPEC covers assets world-wide. The receipt of a Certificate of Non-Availability (CNA), certifies that the Industrial Plant Equipment (IPE) is non-available in DoD inventories. Also, the CNA is now valid for a period of 90 calendar days instead of the previous 45 days.

(5) Specifications. These must be very detailed. The manufacturers brochure is not sufficient. Use Military Specifications (Mil Specs) prepared by DIPEC, or use them as a guide in preparing special needs. There is a need to establish a position or skill for writing specifications. It requires personnel who are trained and capable.

(6) Site Preparation. Must be considered in advance of delivery of machine. Prepare in accordance with drawings, details, and requirements specified by manufacturer. Let concrete cure for a period of 30 days. If done properly, a sound foundation, complete with isolation pads, will result.

(7) NC Hardware. Due to types of workload and methods being used, and the results of the Workload Mix Evaluation, it is recommended that an NC Automatic Bar Chucker with a 16 inch swing, and a Punch Press with a Laser Cutting attachment be requested. Both appear to be justified, and would be in addition to existing NC machines, or those that have been requested in the current DMPE submissions.

(8) Tooling. These must be defined early, and included with purchase of the machine. They must be compatible with the machine. Include in specification.

(9) Spare Parts Kit. Vendors are identifying high mortality items for kits. Availability of kits on site can greatly reduce machine down time, and eliminate requisitioning delays.

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(10) Utilization. Must maintain good records. Traditional reports are not adequate to explain NC Machine use or non-use. Recommend that an 8 position manually operated time meter be used to record non-productive conditions, such as: No Tape, Set-Up, No Operator, No Tool or Material, Corrective Maintenance, etc. Eventually, the computer program may provide meaningful data.

(11) Parts Programming. Clarified the conditions on use of common programming languages versus the use of individual machine languages. Also discussed need to establish effective programming element with trained personnel.

(12) Maintenance. Mechanical and Electrical Maintenance is to be supported by Equipment Management Division. Electronic Maintenance for Computers and Software devices to be supported by ATE Branch. Must establish and use trained personnel. Maintain continuous training. Keep personnel informed of new systems being requested.

5. On 3 May 1979, the team met with personnel of Equipment Management Division, Directorate for Services. Those in attendance were:

Jerry Christesson, C, Equip Mgt Div  
William Achuff, Actg C, Pgm & Mgt Br  
Dean Missimer, Gen Foreman, Mobile Equip Sec  
Takeshi Yamada, Gen Foreman, Ind Equip Sec  
James Goodrich, Leader, Ind Equip Sec

A discussion was held regarding the study and the extent of investigation completed. Specific topics affecting Equipment Management Division, were explained as follows:

a. Authorization. Told about changes in definition of NC/CAM as DMPE, not as ADPE. Changes are forthcoming in "NEW START", and an increase in threshold to \$100,000 Capital Investment. Also, variance in using DD Form 1106 in lieu of an EA for replacement equipment. Talked about TDA interim authority on DMPE. Also conveyed information about funding and DIPEC changes.

b. Maintenance. EMD is responsible for Mechanical and Electrical Maintenance. They were notified of the number of training spaces requested from AMETA for such training. Personnel expressed concern about knowing what items of equipment to support. They do not have advance knowledge of machines. Better coordination and exchange of information is desirable. It is recommended that coordination be accomplished during initial determination and planning, and be a continuing factor. EMD should be represented on the NC/CAM Committee.



7 May 1979

SUBJECT: NC/CAM Study - Implementation at Sacramento Army Depot

c. Other Topics. Other topics described earlier were discussed. These include acquisition procedures, site preparation, spare parts for maintenance, specifications, utilization criteria and measurement possibilities, TDA processing, and DMPE procedures.

d. EMD voiced general acceptance of the study, and indicated their eagerness to support the concepts and establishment of a fully operational NC/CAM facility.

6. On the afternoon of 4 May 1979, an exit briefing was provided to the Directorate for Maintenance. The results described earlier were provided. In addition, copies of the Workload Mix Evaluation statistics for all parts evaluated were provided, together with forms, explanations, and overall summary reports. The projection for SAAD indicates that a possible saving of 15,644.6 manhours can be realized annually if NC/CAM is thoroughly implemented. This equates to a dollar savings of \$177,722.66, based on a Direct Labor rate of \$11.36 per bench hour. Further, the manhour saving approximates a 7.52 man-year saving, assuming one shift operation, or 3.76 manyear, assuming two shift operation.

7. Study Group Recommendations:

a. Establish and staff NC Coordinator at Division level, and allow freedom to perform full responsibilities.

b. Establish and train Parts Programmers at earliest possible time. Organize and staff to Production Engineering Division.

c. Initiate widespread Public Relations Program to acquaint shop and other depot personnel with benefits and uses of NC/CAM. Eliminate fears!

d. Establish NC/CAM Committee and include representatives from Equipment Management Division and Quality Assurance.

e. Define training requirements and establish type of training (on or off depot) and establish schedule.

f. Prepare and submit DMPE Source Documents and associated documentation for NC Automatic Chucker (with 16 inch Swing), and a Punch Press with a Laser Cutting attachment. Include in earliest DMPE program year.

g. Establish meaningful measurement of NC Machine utilization. Use 8 position manually operated time meter to record non-productive operating conditions. (Note: Information and wiring schematic for such a device is available with the Study Group.)

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SUBJECT: NC/CAM Study - Implementation at Sacramento Army Depot

h. Use throwaway tool cutter inserts in Machine Shop. They can save considerable time and effort. The shop was observed using standard tool cutters, which have to be periodically reground and reset for use. Kenmetal, Adamas, and other manufacturers, are willing to explain and demonstrate the use of their tool cutter inserts. We recommend contact be made.



RUSSELL E. HARRIS  
Project Leader  
DESCOM NC/CAM Study Group



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SDSSA-C

16 May 1979

SUBJECT: NC/CAM Study - Implementation at Corpus Christi Army Depot

1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at Corpus Christi Army Depot during the period of 7-11 May 1979. The implementing team consisted of:

James Shindle - LEAD (Team Chief)  
Martin Pickle - NCAD  
Marshall Foster - RRAD

2. Personnel attending the initial pre-briefing session on 7 May 1979 were:

Dr. Hans Freeman, Civilian Executive Assistant  
Mr. J. B. Jones, Deputy Director for Maintenance  
Mr. Don Wells, Chief, Production Engineering Division  
Mr. Jim Welch, Chief, Components Division  
Mr. Frank Gross, Chief, Tool Design Section  
Mr. Ward Whitehead, Chief, Accessories Branch  
Mr. A. Hawkins, Industrial Engineering Division

3. The pre-briefing consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at Corpus Christi Army Depot. The presentation was well received, and personnel were very receptive to the NC/CAM Study. The following is a resume of the comments and discussions during the question and answer session:

a. Dr. Hans Freeman inquired if the training allocations mentioned in the briefing were a firm allocation or recommendation. Mr. Shindle responded by saying that the training courses were recommended to AMETA based on the results of the in-process review conference held at CCAD in January 1979. Mr. Al Takemoto, a member of AMETA, was present and discussed the course topics at that time. The estimated number of participants from each installation was furnished to AMETA for budget purposes.

b. Dr. Freeman also inquired if the NC/CAM Study Group had considered any guidelines to separate DMIS Programming personnel from NC Parts Programmers. He indicated that if not, then they should be. Mr. Shindle indicated agreement with the question, and stated that NC Parts Programmers must have sound knowledge of machine shop practices. There is a difference in skill requirement. A more detailed explanation will be provided in the final report submitted to DESCOM at a later date.

c. Dr. Freeman also commented on the savings to be derived from NC/CAM. After the Economic Analysis (EA) is submitted, acquisition has occurred, and the equipment is operational, how are savings derived? He indicated that NC entails an increase in overhead, such as, programmers, NC Coordinators, etc. Mr. Shindle acknowledged the overhead expense might increase initially, but the real savings from NC/CAM is derived from the total system. That is, by repeat orders, reduced operating times, reduced set-up times, reduced scrap, and reduced utility consumption. In the long run, NC/CAM is more economical.

d. Mr. Frank Gross stated that depots should look for candidates for Programmers with at least 5 years experience in machine shop work. They have to know the machines, the cutter paths, speeds, feeds, type of material, etc. He also indicated that the replacement ratio for machines at CCAD is three conventional to one NC.

4. A tour of the facility was taken, and team members discussed the study with various personnel during the remainder of the week. Discussions were generalized as follows:

a. Shop personnel were very knowledgeable about NC/CAM, and were eager to share their experiences with the study team. Their comments and recommendations include:

(1). Tool Changers. When ordering an NC Machine, random type tool holders are more versatile, and should be considered.

(2). Spindle Noses. A standard or common type was agreed upon for providing the best interchangeability of tooling between machines. It is recommended that quick change tool holders be used for those machines with different size tapers.

(3). Spare Parts Kit. These kits as well as tooling and fixtures should be included in the specifications, and acquired with the machine.

(4). Tool Room Area. The shop has a systematic method for storing machine tooling. A tool sketch is on the inventory card, giving storage location. It is a quick reference system.

(5). Electron Beam Welder. Demonstration was very impressive. There appears to be many uses for this machine. Other DESCOM depots should explore uses for this type of machine.

(6). NC Maintenance. The grade of NC Maintenance personnel should be one grade higher than other maintenance employees due to the complexity of the equipment and the need to retain trained and qualified employees.

b. Computer Hardware, Software, Parts Programming, Controller, Interactive Graphics, CAD, and CAM.

(1). Computer Hardware and Software is on contract maintenance. The contractor makes necessary updates and repairs when called.

(2). Software. Unigraphics language is being used for the Interactive Graphics system. Also available for parts programming is the UNIAPT language. It is recommended that if unigraphics is purchased, be certain to send the programmer to the UNIAPT school.

(3). Programmers. It is imperative that persons have a machinist background, preferably with drafting and tool design.

(4). Specifications. Be certain that sufficient tape storage capabilities are included in specification. Two hundred feet of tape for NC Mills (3 Axis) and One hundred feet of tape for lathes (2 Axis).

(5). Other. Also recommend that memory storage, high speed punch, cassette tape, high speed reader, and cutter compensator in the Controller be included in CNC Machines.

c. Equipment Management Division. CCAD is very fortunate in that all activities have a close knit responsibility and degree of cooperation. There is no conflict between requesting activities and EMD. They have a common goal. Topics discussed:

(1). Authorization. Discussed some of the improvements in the authorization cycle. The DMPE Source Document approval letter will contain a statement that interim TDA authorization is granted to allow procurement action to start in lieu of waiting for the item to appear on the published TDA. He was aware of this change. Mr. Potter also stated that he would not purchase a major item of equipment locally. Regulations require the Item Manager (at the MRC) to purchase the equipment, unless there is no standard item available. Local purchase authority must be granted by the NICP. He was also told that NC/CAM is considered as DMPE and not ADPE. A letter of clarification secured from DARCOM, dated 23 March 1979, is on file. The OMB Circular A-76, dated 29 March 1979, changes the "New Start" requirement to cover a new function only. Equipment to be defined as "Expansion", and with a higher dollar threshold. DD Form 1106 can be used for replacement of equipment in lieu of an Economic Analysis. The EA has to be validated by the Comptroller.

(2). TDA. The DMPE approval letter includes interim TDA authorization to initiate procurement action. The item of equipment must be submitted in the next update of the TDA.

(3). Maintenance. EMD is responsible for mechanical and electrical maintenance of NC Machines. There is a continuing need for training of employees and to retain those employees after training. Often after an employee receives extensive training in these areas, he (or she) is lost through promotional opportunities. It is requested to emphasize the need to elevate the grades of maintenance employees to provide continuing security for these employees. The WD grade system with a higher pay incentive, was suggested as a possible alternative for retention of trained employees. Also, it was recommended that contract maintenance with a training package be established for one year.

(4). Other. Discussed other topics such as; utilization, site preparation, spare parts kits, specifications, and DIPEC Certificates of Non-Availability.

d. Engineering - Industrial Engineering Office.

(1). Authorization. NC/CAM is DMPE, not ADPE. A copy of the clarification letter was provided. The "New Start" definition was discussed. Also "Expansion" for equipment. The team was asked if a new workload on "Black Hawk Engines" was considered as a "New Start". They were told to discuss this with their CITA Coordinator. They were also advised that a DD Form 1106 could be used for a replacement machine tool in lieu of an Economic Analysis. A copy of DD Form 1106 was provided along with the regulation number for instructions on how to complete the form. Advised that the EA must be validated by the Comptroller.

(2). TDA. DMPE approval is tentative TDA authority and requisition and/or procurement action can be initiated. The item must be submitted to the next update of the TDA.

(3). Funding. O&MA has been changed to PA funds. This was for approval authority, but the funds were not transferred, nor were they in the original budget or appropriation act. As a result, very little funds for FY-79-80 are available. The QRIP program is being increased. The new threshold is \$100,000, and with a 3 year payback period.

(4). DIPEC. Screening by DIPEC covers assets worldwide. The issue of a CNA (Certificate of Non-Availability) certifies that the equipment is not available in DOD inventories. Also, the CNA is good for 90 calendar days, instead of the previous 45 days.

(5). Specifications. These must be very detailed. A manufacturers brochure is not sufficient. Use MIL Specs whenever possible, or use as a general guide in preparing special needs. It is easy to use them as part of the Procurement Specification.

(6). Site Preparation. This must be considered in advance of delivery of the machine. Let concrete pads cure for at least 30 days. Make sound foundation with correct isolation pads. Foundation drawings can be secured from the manufacturer.

(7). Spare Parts Kits. The vendors are identifying high mortality items for the kits. The availability of kits on site, can greatly reduce down time of a machine.

(8). Tooling. Must be identified and included early with the purchase of the machine. Identify in specs.

(9). Utilization. Must maintain good records. Manual actions may be necessary initially, but a computer program may provide meaningful data later. For the interim, recommend an 8 position, manually operated time meter to record non-productive conditions, like No Tape, Set-up, No Operator, No Tool or Material, Corrective Maintenance, etc.

e. Comptroller Directorate. Economic Analysis validations.

(1). It was questioned as to where the major savings were derived from, by use of NC Machines, with a given increase in overhead costs. The consensus was that the manhour savings and the reduction in corrective maintenance were the two major areas of savings for NC Machines. However, it must be stressed, that machine utilization is the key to realizing these savings.

(2). The locally prepared "Economic Analysis Handbook", which spells out what should be included in an EA seems to be very helpful for those who are tasked to initiate EA's.

(3). The use of local regulations state that only those requests that exceed the dollar limit of \$25,000 have to be validated by the Comptroller. This does not relieve the requesting organization from preparing EA's with a lesser dollar value.

f. Quality Assurance Directorate. Inspectors on Machine Shop floor advised that all rework material done on NC Machines are inspected 100%. The reason being that even though all parts are identical when manufactured, they do not all wear the same, therefore they must be inspected 100% after rework. For those items manufactured on NC Machines from raw materials, they require only first piece inspection and then random sampling inspection. In the case of CNC Machines, where the machine is programmed at the site, whenever there is a change in operators, then the first piece is inspected also to assure that no changes was induced by the operator.

5. Study Group comments and recommendations:

a. The Depot Commander can be very proud of his installation and managers. They are forward thinking and eager to do a creditable job. It is very evident that CCAD is on top of modernization planning, by keeping up with the latest state of the art equipment.

b. It is recommended that an NC Coordinator be established and staffed at Division level, and allow freedom to perform full responsibilities.

c. Establish an NC/CAM Committee to help the NC Coordinator to develop and expand concepts and reduce operating costs. The committee should consist of representatives from all organizations.

d. Define training requirements and establish schedule.

e. Concur in the acquisition of CNC Chucker Lathe, CNC Tube Bender, NC Milling Machine, CNC Vertical Mill, and CNC Horizontal Mill as originally determined and submitted by CCAD.



Russell E. Harris  
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DESCOM NC/CAM Study



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SDSSA-C

17 May 1979

SUBJECT: NC/CAM Study - Implementation at Anniston Army Depot

1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at Anniston Army Depot during the period of 7-11 May 1979. The implementing team consisted of:

Roy Oliver - CCAD (Team Chief)  
William Humenick - SAAD  
Edward Slimak - TOAD

2. Personnel attending the initial pre-briefing session on 7 May 1979 were:

Lt. Col. Philip Sands, Comptroller  
Mr. Jerry Marks, Chief, Industrial Engineering Branch  
Mr. Richie Owens, Mechanical Engineer, Production Engineering Division  
Mr. Ken Reid, Chief, Production Engineering Division  
Mr. Louis Sutherland, Industrial Engineer  
Mr. Luther Ward, Chief, Equipment Management Division  
Mr. Virgil Brooks, Chief, Shop Equipment Branch  
Mr. A. C. Cheetwood, Equipment Specialist, Production Engineering Division

3. The pre-briefing consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at Anniston Army Depot. The presentation was well received, and a question and answer session concluded the pre-briefing.

4. A tour of the facility was taken, and team members were able to observe operations and equipment.

5. The remainder of the week was devoted to discussions with various personnel. Specific details and clarification of topics were provided, as follows:

a. Comptroller Directorate, Industrial Engineering Branch.

(1). Anniston Army Depot has an existing NC Lathe and three additional NC Machines that are being used and operated manually; not as NC. The basic reasons are due to problems with the control unit, or they were not originally installed to operate as NC.

(2). Additional machines are on the DMPE program; NC Lathe (2 each), NC Fabricator Punching Machine, and a CNC Milling Machine. These equipments have been justified and approved, and funds have been provided, but they have not been able to procure. The hangup seems to be in the procurement cycle at higher headquarters. Attempts are underway to solve this delay.

(3). It is generally felt that the depot has the personnel and the skills necessary to implement an NC program.



(4). The study team identified the changes in the "New Start" requirement, TDA approval, Source Document submission, and use of DD Form 1106 for justification of NC equipment. The depot definitely feels that these changes will be beneficial to them in equipment requests.

**b. Shops Division.**

(1). They are very supportive in obtaining additional NC equipment. They are extremely satisfied with the existing NC Lathe.

(2). They expressed their feeling that a central coordination point should be established that would provide specific guidance and support in the implementation and operation of an NC program.

(3). Three people have had training in programming. At the moment, there is no job description for NC Operators or for NC Programmers. One should be established.

(4). Maintenance personnel have not attended any training for the CNC Lathe. This creates a problem in trying to provide support.

(5). A discussion was held regarding two Fostic NC Boring Machines that are inoperable as NC. The shop indicated that a vendor had been called to provide an evaluation. The study team recommended that a follow-up be made to expedite getting these machines back into working order.

**c. Production Engineering Division.**

(1). They screen DIPEC items. They also pointed out that there was another NC Machine in Building 130 that had been picked up from DIPEC. It is a Lucas Horizontal Boring Machine, which was mentioned earlier, but is not being used as an NC Machine at the moment. Apparently it has not been installed to operate as an NC.

(2). They have been experiencing problems with TDA approvals. To date, they have not had TDA approval with return of Source Documents.

(3). The study team informed them about some equipment listings that are available, which identifies equipment life expectancies, and cumulative cost of maintenance. They were not familiar with the listings. They were told that this information, which is readily available, could be used in the development of their modernization plans, and also to aid in justifying their equipment.

(4). The possible use of Interactive Graphics was also discussed. It was indicated that they have very little design work being performed at the depot, and therefore, it was not recommended that they try to get into graphics at this time. They should continue to monitor their effort and reevaluate this need at a future date.

**d. Facilities Engineering Division and Equipment Management Division.**

(1). Facilities Engineering is responsible for the maintenance and installation of equipment. They are also responsible for contacting vendors for evaluation work. They had contacted Fostic earlier regarding the two inoperable NC Machines. One item of information secured from Fostic was that the personnel who were experienced were no longer in the employment of Fostic. It was understood that an estimate was provided that to replace the controls on the machines, would cost an estimated \$25,000 each. This does not include the cost of any other modifications

to the equipment that may be required. They are old machines and not capable of today's requirements. They were received from DIPEC several years ago. The same condition exists with the Lucas Boring Mill. It will be expensive to update. However, other companies may be able to do the work at a reduced cost.

(2). In contact with Equipment Management Division, they are responsible primarily for Property Book Accountability and the processing of equipment requests for approval, funding and follow-up. They were informed about the specific details clarified for authorization and funding.

**6. Study Group comments and recommendations:**

a. There was some misunderstanding of NC/CAM and its applications. It is recommended that selected personnel be scheduled to attend an AMETA course on NC for Technical Middle Management. They do not have to be managers or supervisors. This will provide a better overview and application understanding for NC systems.

b. Responsibilities are not well defined and assigned. It is recommended that an NC Coordinator be established and staffed at the Division level, and to allow the individual freedom to perform full responsibilities, in support to all organizations. Also, establish an NC Committee, consisting of representatives from all organizations. This committee can help the NC Coordinator in developing and expanding the NC concepts.

c. Organizations are not totally familiar with equipment listings, which apparently are readily available. Some of these listings are available on the depot, while others are available from DESCOM. One such program is the CEDRS program. The data could be very useful for planning and developing justification for requirements. It is recommended that such listings be secured and disseminated to all affected organizations.

d. Three NC Machines were observed not being used as NC. It is recommended that action be taken to contact manufacturer representatives immediately and get the controls updated. It is best to shop around, and get the best return. Also, complete the installation of the Lucas Boring Machine so it can be used as an NC Machine as designed. Also, send the Programmers to the vendors training.

e. Planned NC equipment program. It is recommended that a CNC Machining Center be acquired. It must have contouring capability. Also, based on an evaluation of the earlier Work Mix Evaluation, it is recommended that an NC Bar Chucker Lathe be acquired.

f. Personnel have not been trained by vendor on existing CNC Lathe. It is recommended that in order to obtain full capability or utilization of the machine, that operators, programmers, and maintenance personnel be scheduled to attend the vendors training course. Such costs should normally be included with the purchase price of the machine.

g. The preparation of specifications is a very necessary event prior to the acquisition of an NC Machine. Due to the extensive

amount of details required in such specifications, and due to the lack of qualified specification writers, it is recommended that the depot use MIL Specs as written by DIPEC. If not directly useable, they can be adjusted or modified for special circumstances.

h. There is a possible use for Robotics at Anniston. This was discussed earlier with Lt. Col Sands. He is very concerned about some of the operations from a safety standpoint. The study team indicated that robotics could be useful, and copies of brochures would be sent to Col Sands.

7. After concluding their week long visit, the study team provided an exit interview with:

Col. George Aiken, Commander, Anniston Army Depot  
Mr. C. F. Jefferson, Chief, Management Engineering Division  
Mr. Nathan Hill, Comptroller  
Others

Colonel Aiken was very concerned about the procurement cycle in acquiring equipment. He wants to see something done toward reducing this problem. He inquired if this study was going to address this problem in our final report to General Welch. He was told that such problems would be included and that the final report would contain recommendations as well as actions accomplished.



Russell E. Harris  
Project Leader  
DESOM NC/GAM Study



**DEPARTMENT OF THE ARMY**

**SACRAMENTO ARMY DEPOT  
SACRAMENTO, CALIFORNIA 95813**

**SDSSA-C**

**17 May 1979**

**SUBJECT: NC/CAM Study - Implementation at Letterkenny Army Depot**

**1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at Letterkenny Army Depot during the period of 7-11 May 1979. The implementation team consisted of:**

**Bernard Grindle - SAAD (Team Chief)  
Ray Soden - SAAD  
Henry Musso - PUDA**

**2. Personnel attending the initial pre-briefing session on 8 May 1979 were:**

**Mr. Robert Finley, Deputy Director for Maintenance  
Mr. Ray Amicone, Chief, Production Engineering Division  
Mr. Gerald Cline, Production Engineering Division  
Mr. Hugh Weisman, Production Engineering Division  
Mr. Richard Cadori, Production Engineering Division  
Mr. Seth Schaffer, Production Engineering Division  
Mr. George Nichols, Production Engineering Division  
Mr. Ray Mickley, Foreman, Sheetmetal Shop  
Mr. Ken Kauffman, Assistant Foreman, Machine Shop  
Mr. Charles Farnor, Assistant Foreman, Vehicle Shop  
Capt. Gerald Crocker, New Chief, Production Engineering Division**

**3. The pre-briefing consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at Letterkenny Army Depot. The presentation was well received and personnel were very receptive to the NC/CAM Study.**

**4. A tour of the Machine Shop and Sheetmetal Shops was taken. The tour was conducted by Mr. Gerald Cline, Mr. George Nichols, Mr. Ray Mickley, and Mr. Ken Kauffman. Team members were able to observe operations and equipment.**

**5. The remainder of the week was devoted to discussions and clarification to various personnel. Specific details and clarification of topics is as follows:**

**a. During the tour, it was noted that there were a large number of older conventional machine tools. The team was informed that 50% of the workload in the Machine and Sheetmetal Shops had no drawings assigned, and therefore, did not appear in the Mark Mix Study. The team covered the new Machine Shop building which will be operational in late 1979.**

**b. Mr. Ray Amicone briefed the team on the shop layout, and explained the workflow. The team suggested that the NC Machining area be isolated. This recommendation was accepted.**

c. During the tour of the Sheetmetal and Small Parts Shop areas, the team suggested that the NC Punch Press be isolated from other machines. Of particular concern was the fact that several large Drop Presses are operating in the area, and which could set up vibrations which are very detrimental to electronic controls.

d. During the discussions with personnel, every topic was addressed. Specifically, discussions on the use of the APT language, and the many derivatives, such as; UNIAPT, ADAPT, and the new version, MINIAPT, were of interest.

e. Acquisition lead times came under discussion. It was pointed out that many of the problems are caused by certain regulatory requirements, but if appropriate, recommendations for change will be submitted.

f. The study team explained the new thresholds for funding, and the new limitation for QRIP, or Fast Payback items. It was pointed out, that the NC/CAM Study Group had been successful in getting some restrictions corrected, and some streamlining of the acquisition system is now in effect.

g. It was pointed out that NC Equipment is classified as DMPE, and not ADPE. A letter of clarification has been received from DARCOM.

h. A discussion was held regarding training. The team was notified that Mr. Jim Young and Mr. Al Takemoto, AMETA, had given the NC Orientation for Middle and Top Management course at Letterkenny Army Depot during the month of October 1978. LEAD is expecting to have all operational training requirements done during April 1981.

i. A discussion was held regarding the new Computer program on Work Mix Analysis, which is currently being written by LSSA. The program will enable depots to maintain information and data on workloads, so that a variety of information can be readily available to support and assist in justifying new and replacement equipment, but also to have a projected evaluation of future work load requirements for workloading and scheduling,

j. The study team explained the Work Mix Study, and presented statistics showing the manhour and dollar savings which could be achieved due to the evaluation of the workload accomplished to date. The figures were readily accepted and will be used in various Economic Analysis.

k. A discussion was held regarding equipment. Based on the results of the previous work mix study, the team recommended an NC Punch Press with a Laser Cutting attachment (or Plasma Arc Attachment); an NC Automatic Bar Machine with 16 inch swing; an NC Vertical Milling Machine with 3 axis capability; and a Graphic System. The team also recommended that further work mix studies be conducted to determine the possible justification for a large swing NC Lathe. Also discussed was a graphic system, and copies of brochures were left.

l. The team further explained the need for specifications and the degree of detailed specifications that are required. It was pointed out that MIL Specs would greatly reduce the amount of effort by a depot, but they could be modified to fit a specific need.

m. On the subject of Spare Parts Kits, the team recommended that a careful study be made as to the need for them. It could be useful in helping to restore a downed machine in a shorter period of time. If kits are determined to be essential for a given machine, then they must be determined and acquired at the time the basic machine is purchased.

n. The team recommended, and the group agreed to use the machine manufacturer's specifications and details for the preparation of a site. A successful operation cannot be guaranteed without having a sound and proper foundation.

o. The team was notified that Mr. Jim Shindle (a member of the NC/CAM Study Group) has been designated as Letterkenny Army Depot NC Coordinator. The team recommended that in order for him to perform his responsibilities satisfactorily, and to keep LEAD on board with NC/CAM concepts, he must be staffed at such a level to allow him freedom to carry out his functions. Also, the team suggested the establishment of an NC Committee to provide a method for solving many of the problems, and to assist the NC Coordinator. The recommendation was accepted, and more members will be appointed to the committee.

p. The team commended the depot on the advance work done for the study. They were very complimentary of the cooperation and assistance provided.

q. It was pointed out that the workload not reflected in the study, would improve the manhour and dollar savings shown in the Work Mix Summary sheets. It was suggested that efforts be taken to continue to evaluate the workload. Additional requirements will be forthcoming.

6. An exit interview was conducted on 10 May 1979, with the following personnel present:

Col. Rollin Shaul, Director for Maintenance  
Mr. Hugh Weisman  
Mr. Richard Codori  
Mr. Robert Finley  
Mr. Gerald Cline

A. .  
A capsulized report of the prior meeting was provided, including the manhour and dollar saving generated from the Work Mix Analysis Evaluation. A copy of the summary sheet was given to Col. Shaul. It was pointed out that it was urgent to complete and submit a list of personnel for training. Explanations were given regarding the NC Coordinator, NC Committee, and all other topics.

7. Study Team comments and recommendations:

a. The study team recommended that the Machining area be isolated in the shop layout. Also, that the NC Punch Press be isolated to eliminate any vibration problems from large Drop Presses.

b. Recommend the acquisition of the following NC Machines. An NC Punch Press with Laser Cutting Attachment (or Plasma Arc); An NC Automatic Bar Machine with 16 inch swing; an NC Vertical Milling Machine with

three axis capability; and an Interactive Graphis System.

c. Recommend that a continued Work Mix evaluation be done to determine if justification can be developed for a large swing NC Lathe.

d. Recommend that careful evaluation be made prior to purchasing a spare parts kit, to acquire exactly what is needed for a given machine.

e. Recommend the establishment of an NC Committee, comprising representatives from all organizations.

f. Recommend that an updated list of personnel scheduled for appropriate training be prepared and submitted to AMETA for earliest accomplishment.



Russell E. Harris  
Project Leader  
Descom NC/CAM Study



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SACRAMENTO ARMY DEPOT  
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SDSSA-C

21 May 1979

SUBJECT: NC/CAM Study - Implementation at Pueblo Army Depot Activity

1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at the Pueblo Army Depot Activity during the period of 14-18 May 1979. The implementation team consisted of:

James Shindle - LEAD ( Team Chief )  
Martin Pickle - NCAD  
Marshall Foster - RRAD

2. Personnel attending the initial pre-briefing session on 14 May 1979, were:

Mr. Kenneth Crank, Ch, Missile Systems Division, Dir for Maint.  
Mr. Robert Morris, Ch, Missile Support Branch, Dir for Maint.  
Mr. Charles Gore, Equipment Specialist, Dir for Maint.  
Mr. Jim Mulkey, Foreman, Machine Shop, Dir for Maint.  
Mr. Charles Hook, Equipment Specialist, Dir for Services  
Mr. Don Morgan, Equipment Specialist, Dir for Services.

3. The pre-briefing consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at Pueblo Army Depot Activity. The presentations were well received, and personnel were very receptive to the NC/CAM Study, although it was indicated that the lack of adequate workloads restrict the acquisition of NC/CAM equipment.

4. A question and answer session followed, and the following is a resume of comments:

a. Mr. Kenneth Crank inquired as to which DESCOM Depots currently have NC/CAM equipment. He was told that Corpus Christi has the most, with 9 each now on hand, and with 2 more on requisition. Next is Tobyhanna Army Depot with 6 each NC Machines, followed by Tooele Army Depot with 5 each, and Sacramento Army Depot with 1 each in operation, and two others to be installed.

b. A question was brought out regarding the advantages of NC/CAM over conventional equipment, and whether NC was more suited to large production runs or to small job lots. Mr. Shindle replied that NC/CAM is for small job lots, and that it is very simple to repeat jobs after the initial program has been prepared and written.

c. Team members were told that Pueblo does very little manufacturing. Most orders are for repair of items in support of their missile system repair programs. Therefore, it would be very difficult to justify any NC equipment without the workload to support it.



d. An explanation was given regarding the recent work mix evaluation. It identified the amount of workload that were candidates for NC/CAM. The lack of sufficient workloads produces only minimal results.

e. Mr. Shindle advised the group that recent definition of NC/CAM is that it is DMPE equipment and not ADPE. Also, that the additional authorization channels for ADPE were not necessary to acquire NC/CAM equipment.

f. Mr. Shindle informed Equipment Management Division personnel of the changes in the QRIP program, New Start requirement, and TDA Authorization.

5. A tour of the shop was taken. Teammembers were able to observe operations and equipment.

6. The remainder of the week was spent in discussions with various personnel. Comments and discussions are explained as follows:

a. Discussion with Mr. Charles Hook and Mr. Don Morgan, Equipment Management Division.

(1). Mr. Morgan was asked if the initial briefing and introduction was clear, and if he had any questions. He indicated that it was evident from the workmix evaluation results, that there was little chance of securing any NC/CAM equipment. The work load is not sufficient to justify or support the acquisitions. He stated that they have only one current program, which is the Pershing Missile, which is not current. There is no apparent changes forthcoming unless new missions are assigned to Pueblo Army Depot Activity.

(2). Equipment Management Division submits DA Form 2765-1 as an Equipment Request, together with an Economic Analysis, and sends to Tooele Army Depot for further handling. Preparation of Source Documents and correspondence for follow-up is done by Tooele.

(3). Equipment Management Branch maintains equipment as forecasted in computer printout.

(4). Mr. Morgan stated that the current workload does not even justify retention of existing shop equipments. However, there is no current effort to declare equipment idle for other distribution.

(5). Team members discussed other topics, including acquisition cycle, authorization, and summarized the introduction briefing.

7. Study Team comments and recommendations:

a. Due to the workload situation currently existing, there is no recommendation for the acquisition of any NC/CAM equipment. However, it is recommended that further work mix evaluations be performed on a continuing basis, in order to capture any possible changes in workload that could be used effectively in justifying an improvement in operations

and a reduction in costs. The techniques of the work mix evaluation will be detailed in an upcoming DESCOM procedure, and should be used as much as possible.

b. It is suggested that the establishment of an NC/CAM Committee could be used effectively for the above purpose.

A handwritten signature in cursive script, reading "Russell E. Harris".

Russell E. Harris  
Project Leader  
DESCOM NC/CAM Study



DEPARTMENT OF THE ARMY  
SACRAMENTO ARMY DEPOT  
SACRAMENTO, CALIFORNIA 95813

SDSSA-C

23 May 1979

SUBJECT: NC/CAM Study - Implementation at Red River Army Depot

1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at Red River Army Depot during the period of 14-18 May 1979. The implementation team consisted of:

Roy Oliver - CCAD (Team Chief)  
William Humenick - SAAD  
Mathew Wisniewski - TOAD

2. Personnel attending the initial pre-briefing session on 14 May 1979 were:

Colonel Claude B. Donovan, Depot Commander  
Mr. A. A. Melde, Executive Assistant  
Mr. Robert Mountz, Deputy Director for Maintenance  
Mr. Jack Purcell, Chief, Maintenance Modernization Office  
Mr. William Privett, Chief, Long Range Planning & Engineering Branch  
Mr. Robert Boyd, Public Affairs Office  
Mr. Joe Moore, Chief, Equipment Control Branch  
Captain Gorisheck Production Planning & Control Division

3. The pre-briefing consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at Red River Army Depot. The presentation was well received.

4. A question and answer session followed, and the following is a resume of comments:

a. Environmental problems with regard to NC were discussed. The team recommended that the equipment (NC/CAM) be placed in a controlled environment, but if this is not possible, it was suggested that the NC/CAM equipments be procured with control units that had built-in cooling systems. The team indicated that the equipment would be more susceptible to major maintenance problems if not in a controlled area.

b. The team explained that NC/CAM equipment is now classified as DMPE, and not as ADPE. This clarification was received from DARCOM.

c. Qualification requirements for NC Programmers was discussed. It was explained that Programmers must have a working knowledge of machine tools, an understanding of blueprints and design, and a mathematical background.

d. It was emphasized that Red River Army Depot must select an NC Coordinator and staff him at a division level, with full responsibility to plan, develop and implement an NC program. Also, to establish an NC Committee, with representatives from all organizations, to assist the NC Coordinator in arriving at the various decisions. Included was the special emphasis on early training of operators, programmers, maintenance personnel, and attendance at the NC Orientation Course for Middle Managers at AMETA.

e. A discussion was held regarding the authorization for acquisition of approved items. Approval is interim TDA authorization, but the acquired item must be submitted in the next TDA update. Also, it was pointed out that QRIP dollar thresholds had been increased from \$40,000 to \$100,000.

5. A tour of the Red River Army Depot facilities was accomplished in the afternoon. Team members observed operations and equipment.

6. The remainder of the week, was devoted to discussions with various personnel. Comments were generalized as follows:

a. Machine Shop.

(1). Discussed the type and mix of workload. Explained the results obtained during the early Work Mix Study Team visitations.

(2). Discussed the type of machines that could be of use to the shop. It was observed that most of the existing machines were very old (30 to 40 years old). The work being performed definitely indicates that Numerical Control would be feasible.

b. Sheetmetal Shop.

(1). Discussed workloads, and observed operations being performed. The variety and mix definitely indicates the need for NC equipment.

(2). Workload and conditions can justify an NC Punch Press, and a Programmable Press Brake.

c. Maintenance.

(1). Discussed workload mix with planning personnel. It was indicated that the workload mix represented approximately one third of the total workload requirement, and that it was felt that an additional 25% of the repair work could be performed on NC. This indicates that a substantial increase in savings could be realized if more accurate data was available. It was suggested that workload be continued to be monitored and that data be maintained for use in future justifications.

(2). The team also discussed the use of DD Form 1106, preparation of an Economic Analysis, and the change in "New Start" requirements. Also, the submission of DMPE Source Documents. The DMPE program was discussed in depth.

(3). The team suggested that the depot perform additional evaluation and determine if a heavier duty Punch Press might be more useful than the one currently identified in a DMPE Source Document. It was the general opinion that the Punch Press appeared to be too light for the type of workloads. It was also suggested that they add contouring capability to the CNC Machining Center identified in the DMPE.

d. Comptroller.

(1). It was indicated that they are responsible for validation of all Economic Analysis before submission. They further advised that the use of DD Form 1106, Machine Replacement Analysis, required a statement from the Comptroller that an additional Economic Analysis was not required.

(2). It was agreed that additional personnel should attend and be trained in the proper techniques and procedures of preparing an Economic Analysis.

e. Production Planning and Engineering Division.

(1). It appears that the responsibility for preparing an Economic Analysis is shared with the Planning and the Engineering organizations. Production Engineering provides Economic Analyses for the larger or more complex items. They also provide the specifications. Planning prepares EA's for more routine items.

(2). It was generally agreed that workload data provided by higher command, was not sufficient or timely, therefore making it difficult to justify equipment and facilities. The procedures of the new Work Mix Analysis should provide a better indication of workload needs.

(3). Red River Army Depot had attempted to secure NC equipment in 1971, but for some reason, they were unable to obtain it.

(4). They felt that "higher headquarters" should prepare a "New Start" for new equipment and provide automatic funding to correspond to workloads that have been designated to, and scheduled on depots. They were told that new changes in OMB Circular A-76 will most likely correct the need for a "New Start", unless it is a new mission to the depot.

f. Equipment Control.

(1). It was pointed out that Red River Army Depot is experiencing the same type of problems as other depots in the procurement cycle. It was indicated that they would like to see a more simplified system. It was reported to them that some changes might be forthcoming as a result of the NC/CAM Study.

(2). Discussions were also held regarding authorization, TDA, and funding needs and requirements.

**g. Deputy Director for Maintenance.**

(1). A thorough discussion was held regarding the need for an NC Coordinator. It was pointed out the types of qualifications required, and a copy of a partial job description was provided.

(2). It was also indicated that an NC Committee would be desirable in providing input from all organizations, and therefore, would provide much assistance to the NC Coordinator.

**h. Equipment Maintenance.**

(1). Discussed the importance of a good preventive maintenance program. Also, that it was important to establish a library of PM procedures and manuals on each item of NC equipment.

(2). Advised them that it was important to have all maintenance personnel trained at the vendor's plant for the specific equipments. The team also recommended that this requirement be included in the specifications, along with the need for a spare parts kit.

(3). Red River Army Depot personnel were concerned with the grade level for maintenance personnel, and the problem of keeping qualified personnel. The team reported that this problem was common everywhere, and that a national study was being conducted by the Air Force on this subject. The results could be used by all DOD elements. This problem will be addressed in the final report of the NC/CAM Study.

(4). Personnel reported that there have been problems with their power source. Due to "trash" in the "sine waves", equipment has shut off. The team suggested that if the problem is in the control units, that the vendors be contacted. If it is commercial power problems, then to refer it to Facilities Engineers.

i. Depot Commander, Colonel Claude Donovan, suggested that the new reorganization plan, Disciplined Standard Organization Structures and Staffing (DSOS), be addressed in the final report, so that General Welch will be informed of the impact it might have on the NC/CAM program. He was told that this will be done.

**7. Study Team comments and recommendations:**

a. Recommend that selected personnel be sent to AMETA for the NC orientation for Technical/Middle Management, as an overview and application of NC systems. Also, send personnel to the AMETA course on Economic Analysis.

b. Reemphasize the need to establish an NC Coordinator and also an NC Committee. Provide person with authority and total support from all elements.

c. Make more contact with various equipment vendors. Secure data and specifications for equipment, so that personnel involved with preparing EA's can do a more thorough job. Also, those preparing specifications can provide more realistic requirements. It is recommended that a library of trade literature be established. Visits to other government facilities to observe NC operations would also be beneficial.

d. It is recommended that the Work Mix data be utilized in the justification of NC equipment. Consideration should be given to CNC, rather than straight NC. Industry is going almost totally CNC. Some companies are no longer manufacturing NC systems. CNC, with a built in computer in the control unit, reduces programming time and performs repeat operations from memory. Direct Numerical Control (DNC) is not recommended by the team.

e. Based on the results of the Work Mix Study, performed earlier, it is recommended that a CNC Machining Center, an NC Punch Press, and an NC Programmable Press Brake be acquired. All have been identified in the DMPE program, with the exception of the Programmable Press Brake. The team recommends more detailed evaluation of data to justify this machine.

f. A review of the DMPE program indicates that a Computer was listed. The description on the Source Document, and on the DD Form 1106, is vague. It is suggested that more information be secured, and more justification be provided, before guidance and/or assistance can be provided. It was noted that the nomenclature on the DD Form 1106 needed to be checked for accuracy. The Machining Center identified in the DMPE should include contouring capability.

g. It is recommended that training be secured for operators, programmers, and maintenance personnel. This requirement should be included in the procurement specifications, and that the training be secured from the vendor.

h. It is recommended that spare parts kits be secured for each new machine. Include requirement in procurement specifications.

i. Send personnel to vendors plant to see machine in operation, prior to delivery. Use same personnel to observe machine in operation at Red River Army Depot before acceptance. Also, after a period of one year, send personnel back to vendors plant for follow-up training.

j. Problems in the procurement and acquisition cycle will be addressed in the final project report. Recommendations for simplifying this system will be provided.



Russell E. Harris  
Project Leader  
DESCOM NC/CAM Study



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SACRAMENTO ARMY DEPOT  
SACRAMENTO, CALIFORNIA 95813

SDSSA-C

24 May 1979

SUBJECT: NC/CAM Study - Implementation at New Cumberland Army Depot

1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at New Cumberland Army Depot during the period of 14-18 May 1979. The implementation team consisted of:

Bernard Grindle - SAAD (Team Chief)  
Ray Soden - SAAD  
Henry Musso - PUDA

2. Personnel attending the entrance briefing on 14 May 1979 were:

Colonel Billy Holland, Depot Commander  
Lt. Colonel Charles H. Grayson, Director for Maintenance

3. Colonel Holland inquired about the specifics of the teams mission. He was told that it was to implement the parameters and guidelines as developed by the Study Group. A capsulized description of the concepts, people involved, time frames, and the type of assistance was provided. Colonel Holland gave a brief description of the impending phase-down status of NCAD. However, he felt that the educational aspects of a presentation would be beneficial to the personnel of the varied departments involved. Also, that a posture of readiness should not be disregarded. The Colonel wished the team well on its mission, and requested that he be kept informed of developments.

4. Personnel attending the initial pre-briefing session on 14 May 1979, at 0930 Hours, were:

Mr. Raymond Coffman, Chief, Control Division  
Mr. Brian Watson, Assistant Chief, Production Control  
Mr. James Delaney, Chief, Production Planning & Control Division  
Mr. Garland Clemens, Chief, Scheduling Branch  
Mr. James Schlag, Equipment Specialist  
Mr. Charles Doerson, Assistant Chief, Depot Shops Division  
Mr. Charles G. Bailery, Jr, Chief, Planning Branch  
Mr. Neslao Collins, Chief, Machine Shop  
Mr. Albert Stankiewics, Chief, Sheetmetal Shop  
Mr. Bob Harple, Equipment Specialist

5. The pre-briefing consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at New Cumberland Army Depot. The presentation was well received.



6. The following is a resume of comments and discussions:

a. It was apparent that 90% of the work in the shop area is rework, and were not evaluated during the previous Work Mix Study evaluation. Consequently, only two actual work orders had been evaluated and estimated.

b. A question was discussed regarding proprietary items when no prints or drawings are available. Such items could be handled as sample manufacturing in the Machine Shop. There would be a problem if the work was contracted out.

c. A discussion was held regarding skills that are needed, and the team explained the type and different training requirements. Some people questioned the result if people were trained at AMETA courses, but the actual machines were never secured. The team explained that operator and programmer training is usually given by the vendor after the machine has been acquired. It was pointed out that the courses outlined to AMETA were more for Middle Management and Coordinators.

d. A question was then brought forward with respect to acquiring the machines. They were interested in the procedures and requirements. The team explained the QRIP program, and the new thresholds and dollar limits. An explanation of DIPEC was also provided. It was reported that the acquisition procedure was in the process of being shortened. Further work is underway.

7. After review of the varied workload in the shop, the team indicated that they were not satisfied with the Work Mix Study results. An additional random workmix sample was performed by the team. It consisted of six (6) randomly selected items that belonged to a particular "parts family group." The team then provided some mathematical calculations, and came up with an adjusted saving of some 11,856 manhours. This has been equated to an annual savings of \$61,090.00, and 5.7 man years, assuming a one shift operation.

8. During the exit interview, the results of the adjusted Work Mix Analysis was provided. An explanation was given, which resulted in a recommendation for an NC Sheetmetal Punch Press, with a Laser Cutting Attachment, and an NC High Speed Turning Center.



Russell E. Harris  
Project Leader  
DESCOM NC/CAM Study



**DEPARTMENT OF THE ARMY**  
SACRAMENTO ARMY DEPOT  
SACRAMENTO, CALIFORNIA 95813

**SDRGA-C**

**25 May 1979**

**SUBJECT: NC/CAM Study - Implementation at Tooele Army Depot**

1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at Tooele Army Depot during the period of 21-25 May 1979. The implementing team consisted of:

Mr. James Shindle - LEAD (Team Chief)  
Mr. Martin Pickle - NCAD  
Mr. Marshall Foster - RRAD

2. Personnel attending the initial pre-briefing session on 21 May 1979, were:

Colonel H. Miller, Acting Commander  
Mr. Jack Cox, Chief, Production Engineering Division  
Mr. Thomas Eckroth, Chief, Depot Shops Division  
Mr. Lee Williams, Programmer

3. The pre-briefing consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at Tooele Army Depot. The presentation was well received.

4. A question and answer session followed, and the following is a resume of comments:

a. Mr. Jack Cox requested a more detailed explanation of the teams mission and also the workload mix. He was advised that it is a study of materials being manufactured and to identify those that are candidates for Numerical Control. An explanation of the teams mission was also provided, and it was indicated that the main purpose was to acquaint depot personnel with the study and the results to be implemented.

b. Colonel Miller inquired as to who the team would like to contact and talk with at the depot. He was informed that personnel from Equipment Management Division, Engineering, and also Shop, would need to be contacted to provide the full effects of all elements. Colonel Miller suggested that the team also talk with the Ammunition Equipment Office, since they are very much interested in the use of robots in their ammunition process. Colonel Miller suggested that the pre-briefing be presented again to other personnel, and a schedule was established for Tuesday, 22 May 1979. He also requested that he would like to have another briefing at the end of the week.

c. Mr. Jack Cox inquired as to how NC/CAM equipment was funded. He was told that it is funded through the DMPE Program, and also QRIP programs. In other special cases, MM&T funds might be available for first time equipments. He was told that authorization must be first secured through the DMPE program, and in some cases, a New Start might be required.

5. A tour of the depot and the shop areas was conducted by Mr. Lee Williams. Team members observed operations and equipment. It was noted that Tooele Army Depot has 4 NC Machines in operation, and one NC Lathe to be installed and tested. There is an additional DMPE Source Document which is still active for an additional NC Machine.

6. A second briefing session was conducted on Tuesday, 22 May 1979. The following personnel were in attendance:

Mr. John Martinel, Equipment Specialist, EMD  
Mr. Paul Masock, Production Engineering Division  
Mr. Donald Smith, Chief, Welding Section  
Mr. J. Williams, Support Branch  
Mr. Richard Dillard, Production Planning & Control Division  
Mr. Frederick Gardner, Equipment Management Division  
Mr. Ralph Pratt, Production Engineering Division  
Mr. Wayne Johnson, Ammunition Equipment Office

7. The viewgraph presentation was again given. A question and answer session was held, with the following comments:

a. Mr. John Martinel inquired about the requirement for NC/CAM at Tooele. He was of the opinion that there might be some sort of quota. Mr. Lee Williams indicated that there is no quota, but that the acquisition of an NC Machine will depend upon the type and volume of workloads.

b. At the present time, existing NC Machines are due for replacement, having been in use since 1968. Most of the equipment has received heavy usage. Mr. Williams advised that a projected budget was submitted to DESCOM a week ago, which included \$650,000 for NC Machines. Mr. Frederick Gardner inquired as to the disposition of the NC Machines that were located at Frankford Arsenal in Philadelphia. He was told that they had been distributed to Picatinny Arsenal.

c. Mr. Ralph Pratt advised that there was a lot of talk about contracting out. He asked if NC Machines were available, if this would eliminate the need for such contracting. Mr. Shindle indicated that it would certainly enhance a depot's position to perform in-house manufacturing in lieu of contract work.

d. Mr. Wayne Johnson reported that the AEO presently has an NC Robot. The savings have already more than half paid for the equipment. He stated that Tooele had been able to underbid another depot by \$1.50 per round on a special workload because of the robot. Also, he stated that a saving of 40 cents was realized on each round of ammunition produced. They currently have a workload of 3.3 million rounds of ammunition. Mr. Johnson advised that this equipment is available for inspection. He would schedule a tour of the ammunition area and the robot for the team.

8. A tour of the Ammunition Equipment Office was conducted on Wednesday, 23 May 1979. The tour was conducted by Mr. Wayne Johnson. He stated that

their mission was primarily research and development. The robot is manufactured by UNIMATE, and is presently set up to feed three each machines that attach and remove the flare cartridge out of a 40 mm projectile. The robot is programmed to pick up a missile, sense its orientation, deposit the missile on a rack in the machine. The machine then clamps the missile firmly, engages the flare to the socket, and unscrews the cartridge. This is then deposited in the tank filled with water. Then the robot removes the missile and replaces it back on the conveyor belt to another station. This action is repeated with a frequency of six projectiles per minute. Each machine will accept two projectiles at one time. The robot uses a magnetic pickup at the head that can be replaced with an air actuated clamp for heavier loads. Maximum lifting capacity at the robot head is 300 pounds fully extended. This robot is considered to do the work of three men on three machines. The robot has been operating over 2000 hours with very little downtime. Due to the robot's application capability, which is explosives (primarily), the electronic chassis has to be purged with an air filter whenever the robot is turned on to prevent the accumulation of explosive dust in the electronic cabinets. The cost of the robot originally was \$39,975.00. With the additional safety features for ammunition (\$14,000), the total was \$56,000. The approximate savings utilizing the robot is 40 cents per round; and the present workload is to do 3.3 million rounds of ammunition. Thus, the cost of this equipment will be amortized in a very short time. It was pointed out that General Motors and Ford Motor Company are using the same kind of robot to perform welding operations on hard to reach places on an automotive body. The robot provides a considerable degree of safety for an otherwise hazardous and laborious task. The operator stands at a remote site and observes the operation through a window. Without the robot, the entire machine would have to be enclosed with an explosive shield. The team thanked Mr. Johnson for the tour and for the demonstration.

9. A final exit briefing was held for the Depot Commander, who indicated his satisfaction with the implementation, and the degree of information that was provided. He thought that the team had done an excellent job, and was very complimentary of the data provided in the entire NC/CAM Study.



Russell E. Harris  
Project Leader  
DESCOM NC/CAM Study



DEPARTMENT OF THE ARMY  
SACRAMENTO ARMY DEPOT  
SACRAMENTO, CALIFORNIA 95813

SDSSA-C

29 May 1979

SUBJECT: NC/CAM Study - Implementation at Savanna Army Depot Activity

1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at Savanna Army Depot Activity during the period of 21-25 May 1979. The implementing team consisted of:

Mr. Roy Oliver - CCAD (Team Chief)  
Mr. William Humenick - SAAD  
Mr. Mathew Wisniewski - TOAD

2. Personnel attending the initial pre-briefing session on 21 May 1979, were:

Lt. Colonel Joel E. Gregory, Commander, Savanna Army Depot Activity  
Mr. A. J. Dohlgan, Chief, Administration and Services  
Mr. R. H. Felderman, Chief, Mission Division  
Mr. William Hurley, Equipment Manager  
Mr. George Wagner, Chief, Fabrication Shop  
Mr. Martin Sheehy, Machinist Leader

3. The pre-briefing consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at Savanna Army Depot Activity. The presentation was well received, and a question and answer session concluded the briefing. The following is a resume of comments:

a. The requirements for preparing an Economic Analysis were discussed. It was pointed out that this technique is necessary in acquiring equipment. It was pointed out, that the DD Form 1106 can be used in lieu of a full Economic Analysis, when requesting replacement equipment. Savanna indicated that they have not used the form for quite some time, and did not seem to be aware of the EA requirement. Apparently, most of the equipment received in recent years has been obtained from DIPEC, or was replaced because it was worn out and was beyond economic life, and procurement was accomplished with local funds, and without an Economic Analysis. It was noted that all equipment requirements are submitted to DESCOM through Letterkenny Army Depot. Personnel indicated that they would check into their procedures.

b. Personnel were interested in why Savanna had not been included in the Work Mix Analysis study. The team advised them that it was probably due to the fact that there was no Maintenance mission at the installation. Other installations had maintenance missions, and were engaged in some form of workload.

c. The depot has two (2) Numerical Control Machines. They have a DeVlieg Spiramatic Jigmill, and a Burgmaster Drilling, Tapping and Boring Machine. They feel that they have a requirement for an additional NC Jig Borer. It has been justified and has been submitted in the FY-79 DMPE.

d. The team informed the group that DMPE approval serves also as tentative TDA Authority. Personnel indicated that they were not aware of this, nor had they received notification of the action. They indicated that they would check it out. They were also told that when they acquired the item of equipment after approval, that they must then include the item in the next TDA Update action.

4. A tour of the facility was taken by the team. Operations and equipment were observed by team members.

5. The remainder of the week was devoted to discussions with various personnel. Comments were generalized as follows:

a. Workload requirements were discussed. It was pointed out that there is no firm scheduled workload projections beyond the current year. Most of the workload is generally from Ammunition Peculiar Equipment (APE) programs, which is provided by Rock Island Arsenal.

b. Four existing personnel have had a programming course through Army Correspondence programs. A full time Programmer position has not been established. Maintenance on NC equipment is performed by contract by the manufacturer. Other maintenance on other equipment is performed by shop personnel.

c. In discussions with the Equipment Manager, the team provided him with a completed sample copy of a DD Form 1106. They also asked him to verify the nomenclature of the Jig Borer, that had been identified on the DMPE program, to make certain that it was NC. They discussed the importance of submitting correct and useable specifications, and the team provided a list of MIL Specs that currently exists for a variety of NC equipment. The depot does not have anyone specifically assigned the responsibility for preparing specifications.

6. Study Team comments and recommendations:

a. Depot personnel did not appear to have adequate knowledge of current "State-of-the-Art" equipment, or concepts. It is recommended that contact be made with various Machine Tool Builders and secure pamphlets and brochures, and develop a catalog of Machine Tools. Subscribe to trade journals, such as; "Modern Machine Shop", "Metlfax", "Manufacturing Engineering", "Tooling and Production", "NC Comline", etc. Personnel need to have more visibility. Also, attendance at NC/CAM Shows, seminars, etc, is also recommended.

b. The nomenclature for the Jig Borer as listed on the DMPE program doesn't appear to be identified as NC equipment. Recommend that investigation be made and that consideration be given to changing the request to a CNC (Computer Numerical Control) Boring Machine. This machine has boring capability plus much more. It has increased capability/capacity with flexibility at the same approximate cost as the Jig Borer.

c. It is recommended that training for NC Machine Operators and for Programmers be accomplished at the manufacturers facility. Such training should be directed toward the specific equipment existing at Savanna.

d. Identify in procurement specifications the need for a spare parts kit for high mortality items. This will supplement the maintenance requirement.

e. Establish an on-going Preventive Maintenance program. This can go a long way to lengthen the life of existing equipment.

f. Workload is Savanna Army Depots' major problem. As indicated the workload is scheduled on an annual basis by Rock Island Arsenal. There is no long range projections of workload, and this makes it difficult to justify additional equipment, especially NC/CAM. It is suggested that consideration be given to using the Work Mix Analysis evaluation procedure, which is soon to be finalized and published from LSSA. The output from this program could provide great assist in determining future workload trends, as well as assisting in identifying utilization conditions.

g. The team suggested that consideration be given to assigning an individual as NC Coordinator, when additional NC Machines are acquired. With only two NC Machines currently in use, it does not appear to be justified as a full time position at the moment.

7. The team was privileged to visit the Defense Ammunition Center and School, which is a tenant activity. It is a DARCOM activity, and consists basically, of a large design group. Mr. A. C. McIntosh, and Mr. Dick Green were generous in discussing the operation and mission. They were interested in the change in the new OMB Circular A-76, which changes the "New Start" requirement. They indicated that they are requesting an Automated Drafting System. The team provided information on various manufacturers, and they also suggested that because of the type of design work being done, that the center might be able to use an Interactive Graphics System. The personnel indicated interest, and will check further. They indicated that their biggest problem is getting equipment justified and processed through Procurement.



Russell E. Harris  
Project Leader  
DESCOM NC/CAM Study



DEPARTMENT OF THE ARMY  
SACRAMENTO ARMY DEPOT  
SACRAMENTO, CALIFORNIA 95813

SDSSA-C

30 May 1979

SUBJECT: NC/CAM Study - Implementation at Tobyhanna Army Depot

1. Implementation of the parameters and guidelines for the DESCOM NC/CAM Study was conducted at Tobyhanna Army Depot during the period of 21-25 May 1979. The implementing team consisted of:

Mr. Bernard Grindle - SAAD (Team Chief)  
Mr. Henry Musso - PUDA  
Mr. Ray Soden - SAAD  
Mr. Shelley Sewell - ANAD

2. Personnel attending the initial pre-briefing session on 22 May 1979, were:

Colonel R. N. Barker, Depot Commander  
Lt. Colonel Otto Babel, Director for Maintenance  
Mr. William Morris, Deputy Director for Maintenance  
Mr. Anthony R. Trotta, Chief, Production Engineering Division  
Mr. Robert L. Marmo, Chief, Operations Branch, Production Engineering  
Mr. Shelly J. Shirer, Chief, Special Projects & Shop Division  
Mr. Andrew Labonich, Machine Branch  
Mr. Ray E. Adams, Sheet Metal Branch  
Mr. Ralph Wilbes, Chief, Equipment Management

3. The pre-briefing consisted of a viewgraph presentation which highlighted the status of the NC/CAM Study; explained the purpose and need for the study; described the actions taken; explained the elements and topics that were investigated; identified the resultant actions achieved; and identified the plan for implementing the specific parameters and guidelines at Tobyhanna Army Depot. The presentation was well received, and produced the following comments:

a. During the viewgraph presentation, Col. Barker indicated concern over the projected equipment acquisitions (and dollar allocations) displayed on two viewgraphs. It was indicated that the charts reflected the condition as submitted in the 5 year Modernization Program to DESCOM. There was much discussion as to the validity of the information displayed, and Col. Barker directed depot personnel to provide an accurate and up-to-date listing of equipment requests to the team prior to their departure.

b. A discussion was held regarding the acquisition of foreign made NC Machines. The team provided information regarding a waiver secured from Department of Defense which changes the Armed Services Procurement Regulation relative to the "Buy America Act". It was pointed out, however, that the waiver was limited to certain countries only. The team cautioned that extensive investigation into Software and Language acceptance be conducted before a final decision is made to purchase under these conditions.



c. It is recommended that training for NC Machine Operators and for Programmers be accomplished at the manufacturers facility. Such training should be directed toward the specific equipment existing at Savanna.

d. Identify in procurement specifications the need for a spare parts kit for high mortality items. This will supplement the maintenance requirement.

e. Establish an on-going Preventive Maintenance program. This can go a long way to lengthen the life of existing equipment.

f. Workload is Savanna Army Depots' major problem. As indicated the workload is scheduled on an annual basis by Rock Island Arsenal. There is no long range projections of workload, and this makes it difficult to justify additional equipment, especially NC/CAM. It is suggested that consideration be given to using the Work Mix Analysis evaluation procedure, which is soon to be finalized and published from LSSA. The output from this program could provide great assist in determining future workload trends, as well as assisting in identifying utilization conditions.

g. The team suggested that consideration be given to assigning an individual as NC Coordinator, when additional NC Machines are acquired. With only two NC Machines currently in use, it does not appear to be justified as a full time position at the moment.

7. The team was privileged to visit the Defense Ammunition Center and School, which is a tenant activity. It is a DARCOM activity, and consists basically, of a large design group. Mr. A. C. McIntosh, and Mr. Dick Green were generous in discussing the operation and mission. They were interested in the change in the new OMB Circular A-76, which changes the "New Start" requirement. They indicated that they are requesting an Automated Drafting System. The team provided information on various manufacturers, and they also suggested that because of the type of design work being done, that the center might be able to use an Interactive Graphics System. The personnel indicated interest, and will check further. They indicated that their biggest problem is getting equipment justified and processed through Procurement.



Russell E. Harris  
Project Leader  
DESCOM NC/CAM Study

c. A brief discussion was conducted on Post Processors. The team reported that a breakthrough has occurred within industry, and interchangeability of information between machines may now be possible. This was a real problem in the past, especially when different machines were being used, with different languages, etc.

d. Much concern was expressed by attendees regarding the new Work Mix Analysis Evaluation program being developed by LSSA. The main concern appeared to be centered on "more paper processing and the resulting higher overhead expense." The team informed the group that specific information would be forthcoming, to explain how the data is to be developed and submitted, and how it is to be used. It was noted that the program could be beneficial to other program areas, if it is used properly.

e. Funding was brought out as being a major obstacle, particularly for new machine acquisitions. The team explained that replacement of existing machines can be accomplished without the "New Start" requirement. A change to OMB Circular A-76 was published on 29 March 1979. Changes to AR 235-5 is expected within the next 3 to 6 months. Also, an explanation of the new dollar thresholds and pay back periods for QRIP, and Fast Payback Systems, was provided, and their use was urged. There was a question of Sole Source Purchase, and if it was still in existence. The team informed the group, that at this time, Sole Source Purchasing is possible, but demands a considerable amount of justification. In some situations, it may violate existing regulations.

f. The team advised the group that NC/CAM equipment is classified as DMPE, and not ADPE. Information was secured from DARCOM, and DESCOM Equipment Managers have been notified accordingly. Guidance should be forthcoming to each depot in the very near future.

g. Concern was expressed as to the need for a special series and pay schedule for NC personnel. The group did not concur with the recommendation to establish an NC Coordinator. It was stated that after the program had become operational, the position would then become an overhead expense. The Study Team did not agree with this position, and strongly recommended the establishment of an NC Coordinator, and an NC Committee, to insure a coordinated group effort is accomplished by all affected divisions and activities. The team assured the group that a study was being conducted for DOD by the Air Force, to establish a special series for NC personnel.

h. The group expressed concern as to AMETA being the sole source for NC courses. The reason cited, was that courses offered were not current with present state-of-the-art, and perhaps commercial sources should be considered. AMETA courses could be supplemented by manufacturer courses for specific machines.

i. The group was concerned as to whether information and direction will be available after the NC/CAM Study Group had been dissolved. There was some discussion, and the team suggested that perhaps a special staff might be established for on-going assistance and direction. The group concurred that such a DESCOM staff would be highly beneficial.

4. An extensive tour of the depot and the shop area was conducted on 21 May 1979 by Mr. Ed Slimak. A narrative description of various workload missions was provided. During the remainder of the week, discussions were held selected personnel.

5. On 23 May 1979, an exit interview was held with Mr. Bob Marmo and Mr. Ed Slimak. Results of the visit were discussed.

6. Study team comments and recommendations:

a. It is recommended that an NC Coordinator, and an NC Committee be established. The NC/CAM operations require coordinated effort, and evaluation of individual workloads is essential in order to show productivity improvement with reduced costs.

b. It is recommended that efforts be taken to schedule personnel to AMETA courses, and also to other courses that are available from manufacturers and other organizations. The effective and continued operation of an NC/CAM facility requires trained and skilled personnel.

c. The study group concurred with the revised listing of equipment desired, and provided by depot personnel, as directed by Col. Barker. The 5 year Modernization plan is being updated to reflect the new requirements. They are: CNC Drill Router for Circuit Boards; CNC Chucking Lathe; CNC Horizontal Machining Center; Graphic System; and a 45 Ton Turret Punch Press. It was noted that these equipments are in line with the results of the Work Mix Analysis conducted earlier in the year.



Russell E. Harris  
Project Leader  
DESCOM NC/CAM Study

ROUTINE

00482/00271009/144A

JD 144/1528Z

ACTION/INFO: SDSSA SDSSA-AD SDSSA-C SDSSA-M SDSSA-D SDSSA-P SDSSA-S

SDSSA-T SDSSA-Q SELTV CCNC-SAC TDP TPP\* MPO NICO VCTL CIR CSALNO

USNR USMCR USASDRG USMCRS APODET SIAD SHAD HAFB TCC SS DATE-----

RTTUZYUW RUFLNDA1150 1441355-UUUU--RUMFWA.

ZNR UUUUU

R 240720Z MAY 79

FM CDR MZAD GE //SDSMZ-C//

TO CDR SAAD SACRAMENTO CA //SDSSA-C//

BT

UNCLAS

SUBJECT: DESCOM NC/CAM STUDY IMPLEMENTATION

A. YOUR MSG 152230Z MAY 79. SUBJECT AS ABOVE.

1. NEGATIVE REPLY.

2. IT IS THE OPERATING CONTRACTOR'S RESPONSIBILITY TO DEVELOP NC/CAM REQUIREMENTS AT THIS GOCO DEPOT.

BT

#1150

NNNN

Fig. 3-1 DESCOM NC/CAM Study implementation for Mainz Army Depot (MZAD)

ROUTINE



DEPARTMENT OF THE ARMY  
ANNISTON ARMY DEPOT  
ANNISTON, ALABAMA 36201

Reply To The Attention Of:

SDSAN-CD-MD

SUBJECT: NC/CAM Study

Commander

Sacramento Army Depot  
Sacramento, CA 95813

1. Reference: Letter, SDSSA-C, dated 23 May 79, subject: NC/CAM Study - Implementation Results.
2. Since the visit of your implementation group to ANAD, 7-11 May 79, certain actions have been taken to correct or strengthen those problem areas identified by Ref 1. Our primary action has been to consolidate functions involving identification, justification and acquisition of new capital equipment under the Industrial Engineering Branch of the Comptroller's Management Engineering Division. This action includes responsibility for execution of a strong depot initiative toward NC/CAM applications. Hopefully, it will help our NC/CAM position by providing (1) a knowledgeable group of NC/CAM oriented personnel, (2) more clearly defined responsibilities, (3) improved NC/CAM operator training, and (4) increased effort aimed at obtaining additional NC/CAM equipment.
3. Other recommendations of your study group are also being acted upon. Using the data developed by the workload mix study group, we are now preparing economic analyses for an NC machining center and an NC horizontal lathe. Both of these items have been programmed in our FY 81 DMPE Program. Actions on other recommendations, such as DIPEC purchase specifications, will be taken as time permits.
4. Overall, the results of the NC/CAM study to date have been very beneficial to this installation. We expect these to increase even more following implementation of all recommendations such as increased funding limitation on QRIP items.

FOR THE COMMANDER:

  
NATHAN L. HILL  
Acting Comptroller

CF: DRSDS-SI (Mr. Updegrave)

## NC STUDY - FINAL COMMENTS

1. After visiting several of the depots, I have an even better understanding of the need for improved processes/systems and equipment at these facilities.
2. I feel that the approach taken on the study was a good one. I also believe the team accomplished pretty much what it set out to do. This was a very difficult task considering the experience that was available and the scope of the project. If there was any one thing lacking, I guess it would have to be the limited number of people experienced in NC. Now that it is completed, for all practical purposes, I feel that it would have been better had the team been able to specifically identify, down to the type and model, the equipment needed at each depot and even assist in preparing the economical analysis for justification. Then all that would be needed would be approval and funding. Of course, I realize this would probably have taken much more time. Now it is left up to the depots to follow through and I'm not sure that they have the personnel to do so, although in all cases the personnel (management on down) were very cooperative. Anniston and Red River indicated that every effort would be made to get started with an NC program, and would also start out by trying to establish an NC coordinator position. Both installations seem to realize the need for improved facilities and equipment in order to be more productive and more competitive. Savanna just does not have the workload.
3. The members of my team all worked together very well and contributed to the success of the survey. Bill Humenick was most helpful, especially in his area of expertise.
4. The entire survey was well coordinated. The nucleus of personnel assigned worked very well as a team. It has been a pleasure for me to have been a member and respectfully hope that my contribution has been beneficial in assisting the depots in making a big step in improving productivity.

ROY OLIVER  
NC Study Team

Figure 3-3

31 May 1979

**Report from Letterkenny Army Depot**

1. Reference is made to the NC/CAM implementation visit to Corpus Christi, Pueblo and Tooele Army Depots. Personal opinion of each of the activities is as follows:

a. Corpus Christi (CCAD) - Top and middle management were enthusiastic about the study. The team received excellent response and cooperation. Based on the number of NC machines and modernized equipment in use and on order, it was very evident that modernization planning was an ongoing program at CCAD.

b. Pueblo - Middle management was interested. However, with the reduction of work it would be difficult to justify present conventional equipment.

c. Tooele - Colonel Miller was very interested in the NC Study Program. The team received excellent response and cooperation from his office. The AEO Office was also very receptive and gave the team a demonstration of the ammunition robot. In the Shop it was recommended that more people be knowledgeable of the NC program through training at AMETA, and that another programmer be trained as backup.

**JAMES SHINDLE**  
Group Leader, NC/CAM

**Figure 3-4**

## Chapter 4

### SUMMARY OF RECOMMENDATIONS

4-1. The work performed by the NC/CAM Study Group has resulted in the following recommendations, which are supported by the various appendices and depot visitations. Acceptance and adherence to these recommendations will guarantee commonality of NC/CAM operations among the depots, and within the Depot system.

4-2. The Study Group recommends that:

a. For NC/CAM machines:

(1) Specifications for construction and content shall be detailed and specified as described in Appendix D.

(2) Existing conventional machines not be retrofitted to perform as NC machines, unless determined to be feasible and economically justified.

(3) Existing NC machines should be upgraded if technology can be improved within economic limits. (Spare parts must be available.)

(4) Random access tool changers be specified and used, if justified.

(5) Rotary tables with basic indexing systems be specified, when appropriate.

(6) Complete set of operating accessories be included as standard equipment, not as optional.

(7) Consider and justify all required options during initial evaluation and estimation.

(8) Establish shop area for NC machines separate from conventional equipment.

b. For tools and fixtures:

(1) Establish separate tooling sections for NC and conventional machines.

(2) Locate tooling section close to the machines.

(3) Adopt a standardized tool identification system.



- (4) Use a modular tool storage system.
- (5) Use tools with replaceable inserts as much as possible.
- (6) For each job use the shortest and most rigid cutting tool possible.
- (7) Avoid long weak drill shanks and long end mills.
- (8) Design and fabrication of fixtures be done in-house. (Pay attention to interchangeability of fixtures between machines.)
- (9) V-flange tapers for tool holders and head stock spindles be adopted.
- (10) Good tools, even if they have a high pricetag, be specified and used.

c. For computer hardware:

- (1) Computer hardware support for parts programming be established locally at each depot. (Do not create a system with one central computer and communication links to the depots. Allow that the local systems might be integrated into a distributed processing network at a later time.)
- (2) Provisions for computer graphics be included in the computer system for future use, (even if it cannot be justified economically at present).
- (3) Computer hardware support for the work-mix analysis data base be established locally at each depot. (Allow that the local systems will be integrated into a network at a future date.)

d. For controllers:

- (1) New controllers for NC machines shall be softwired.
- (2) New controllers shall possess memory expansion capability.
- (3) It shall be permissible to deviate from existing military specifications and commercial standards whenever this is necessary to permit the use of softwired control in lieu of hardwired control.
- (4) New controllers for NC machines shall, as a minimum, provide the following features:
  - (a) ASCII Code (RS 358) for input.

(b) Absolute and incremental position input.

(c) Input in both metric and British units.

(5) Electronic transmission of control tape information from a computer to the machine control units shall be encouraged. (However, the machine must be equipped with a hardcopy input device on the shop floor as an alternative. The electronic input shall interface "behind the tapereader." The control unit must run based on its memory and independent of the host computer during job execution.)

(6) The collection of machine use records shall be accomplished using digital processors and software in the control unit, as appropriate.

(7) Softwired controllers be protected against unauthorized or incompetent use by software keys. (Passwords that are programmed into the operating software.)

(8) The executive program of softwired controllers possess a modular structure. (Each module shall be documented individually.)

(9) The availability of a postprocessor for the combination of machine tool and controller shall be ascertained before an order is placed.

e. For parts programming and accessories:

(1) The logical format of the APT cutter location file shall become a required standard. (Languages and processors other than APT may be used if they can generate a "CL" file in APT format.)

(2) A system-wide standard for magnetic tapes, which can serve to store and exchange CL files, shall be developed.

(3) Standardized postprocessor commands be employed in new postprocessors as stipulated in the N.B.S. Standard. (Soon to be released.)

(4) An identification system for NC tapes be established. (Stipulate that drawing number and parts programming date are among the identifiers to be used.)

f. Interactive Graphics Systems:

(1) Interactive Graphics Systems be capable of output in the "CL" file format of APT.

(2) They shall permit the user to program his own set of primitives (symbols) into the system.

(3) Operating software packages of more than 256 Bytes shall possess a modular structure. (Each module shall be documented individually.)

**g. Procurement:**

(1) Justification and submission requirements be streamlined. (Make one form applicable to all requirements.)

(2) The objections to productivity improvements, which appear in AR 235-5 and the related DARCOM Supplement 1 be eliminated from the criteria, which NC/CAM projects must meet.

(3) The Industrial Plant Equipment Replacement Worksheet (DD Form 1106) be declared sufficient to fulfill most of the economic analysis requirements.

(4) Letter requests and local forms for the type classification exemption be eliminated. Require that processing of such requests by the US Army Equipment Authorization Review Agency be completed in 15 work days.

(5) The responsibility for LIN, NSN and TDA processing be placed into the same agency and a maximum period be set for its turn-around time.

**h. DESCOM-wide NC Management:**

(1) The DESCOM NC coordinator be empowered to oversee uniform implementation of these recommendations.

(2) A study group for use in NC policy development by DESCOM, and as a consultant for the depots, be retained.

(3) A centralized spare parts inventory not be established.

(4) The definition of "Direct Labor" in NC work be changed to include "white collar work" like parts programming, keypunching and record keeping.

(5) Adjust the depot organization structure and staffing patterns as stipulated in the Disciplined Standard Depot Organization Structure (DSOS) to provide for NC/CAM personnel and functions as contained in this report. Locate all NC personnel in the same organization within the Directorate for Maintenance.

(6) Keep NC parts programmers separate from DMIS programming personnel.

(7) Establish system-wide pay scales for NC personnel.

i. Depot-Level NC Management:

(1) Establish NC Coordinator position.

(2) Establish NC/CAM Committee.

(3) The computerized work-mix analysis data base, described in Appendix E, be established and used by all depots.

(4) The management/labor dialogue, regarding NC as a local responsibility, be conducted.

(5) NC personnel (primarily) be developed by retraining of present staff.

(6) A plan be established for using NC machines normally for a single shift, but enough people be trained to staff two shifts independent of each other during national emergencies.

(7) A system for the collection of utilization records be established, as described in Appendix F. (Require that the automatic collection of use data be addressed in the specifications of future NC machines.)

(8) The postanalysis procedure as described in Appendix F, be adopted.

(9) Participation of maintenance personnel in the deliberations concerned with NC acquisitions, be assured.

(10) Classify NC maintenance personnel one wage grade above their counterparts for conventional machines.

j. NC Maintenance:

(1) In-house maintenance capability be established. DO NOT CONTRACT OUT.

(2) Spare parts inventories, locally and close to the machines, be established. (Begin with manufacturers recommended kit even if that seems expensive.)

(3) A spare tape reader be included among the spare parts for expensive NC machines.

(4) Manufacturer's schedules and procedures for preventive maintenance be adhered to closely. (Introduce changes in the maintenance process only after experience has shown the need for it.)

(5) Written records of all maintenance actions be retained on file.

(6) Establish a library of preventive maintenance procedures.

(7) Establish an on-going local program for maintenance procedures.

k. Training:

(1) Basic NC training (as outlined in Appendix G) for depot personnel be handled by AMETA. Specific machine instruction by vendors should be preceded by AMETA or other government training agency courses.

(2) The recommendations in Appendix G in selecting NC trainees be adhered to.

(3) Training courses to meet the personnel needs identified in Fig. G-1 be implemented during FY 1980.

(4) Continuing training requirement for AMETA be established.

## Appendix A

### NC MACHINE TOOLS & TOOLING

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## Appendix A

### NC MACHINE TOOLS AND TOOLING

#### 1. Introduction.

What is Numerically Controlled Machining? The simplest answer to this question is: "running a machine tool by minicomputer or punched tape to make it produce more for less cost." Numerical Control is simply the putting together of a number of pieces of man's present knowledge and technology to produce a new tool, a new tool that can increase the productivity and reduce the cost of operating a machine tool. Increased productivity and decreased operating costs are mandatory for survival in this present era of mounting inflation and associated labor-material costs.

There is nothing mysterious or difficult to understand about Numerical Control Machine Tools (NCMT). NCMT can be defined as processing material with industrial machinery that is electronically controlled utilizing a minicomputer (or mechanically) and the use of a punched tape as opposed to conventional manual control. Media containing the coded instructions to the machine tool may be (1) a punched tape, (2) a magnetic tape, or (3) a tabulated card fed directly to the machine tool or indirectly via a centralized computer system. The latter know as Numerical Control/Computer Aided Manufacturing. (See Figure A-1.) Basically, the NCMT function in a manufacturing system is to remove metal, plastic, or wood to form a geometric shape by one or a series of methods. These methods would include: milling, drilling, turning, boring, punching, and/or grinding. The end result of the material removal processes will be a marketable product or a component part in a repair sub-assembly.

The purpose of this paper is to define, as far as possible, guidelines for selecting appropriate material removing NCMT and the necessary peripheral tooling. A fact to be borne in mind is that the NC concept, while fast, accurate, and efficient will increase productivity and decrease manufacturing costs, it is not a panacea or a cure-all for all manufacturing system ills. NCMT selection must be made systematically and with specific regard to product, future utilization, amortization, etc.

#### 2. Hardware.

The technology in NCMT capabilities and operating controls is advancing at a very rapid pace, creating a situation whereby a machine might become obsolete before complete amortization can be realized. Machine Tool Builders number in excess of 1,000 at the present time in the United States, plus an unknown number of European and Japanese



firms. Each NCMT builder will field at least two machine types, each with a distinct function, but accomplished in a different manner. This myriad of products renders random NCMT selection highly hazardous, therefore, established purchase and machine criteria are required before a judgment and decision can be finalized for the acquisition of a machining system.

From factual data gathered through visits to services facilities, industrial machine shops and machine tool builders a conclusion can be drawn that job shop type machinery approaches 95 percent of the total machine tool inventory. Job shop machinery includes: lathes, mills, drills, and punch presses. The size and horsepower, of course, will vary in accordance with the end items to be manufactured.

The NC drill has been the most frequent purchase in NCMT, one reason being that drilling is the most common of metal working operations. The NC drill is one of the less expensive NCMT and is quite simple, usually utilizing only the point-to-point positioning method. One of the first savings to be realized from an NC drill will be in the fixture and jig tooling area. With the conventional machine tool, a drill jig had to be built for positioning; in NC, the program positions the drill bit automatically with excellent accuracy and repeatability. Manual layout is eliminated, even on those parts requiring complex or unusual hole patterns. A drilling machine is a machine which holds, rotates, and forces a drill into the workpiece. They run the complete gamut from the very simple to the most complex. However, all drilling machines have functions in common. Basically, there is a spindle to which rotative power is applied and which holds the tool; a table on which the workpiece rests (normally movable); a method of feeding the drill into the work; and a frame for supporting mechanisms. Drills may have single spindles, multiple spindles, turrets or some type of tool changing mechanism. Depending upon their structure, they may or may not be capable of milling. (See Fig. A-2.)

One of the most cost effective assets of the NC lathe is the increase in the chip making ratio. The use of conventional machines result in a loss of time for set up operations, and in loading and unloading of parts. NC lathes are capable of generating contours which are possible on conventional lathes only by the use of slow and expensive forming tools. The NC lathe can hold closer tolerances, and is superior in repeatability. This results in fewer, if any, scrap parts. Conventional lathe work is one area where the manufacture of parts and the human element are interdependent. With the use of NCMT, however, production and accuracy remain constant throughout an entire shift. Examples of lathe parts would include shafts, bearings, bushings, gear blanks, spindles, rods, and sleeves. All lathes, regardless of type, operate on the same basic principle; the workpiece is revolved by power and a cutting tool is brought to bear against it, removing metal in the form of chips.

Although there are many types of lathes, from the NC standpoint, only three need to be considered: the engine lathe, turret lathe, and turning center. The NC operational requirements of these three lathes will, in most cases, fill the requirements of other types of lathes such as vertical turret lathes. (See Fig. A-3.)

The NC mill was devised to cut costs on the manufacture of complex contoured parts. There are many cost savings that can be identified by using NC mills. Fixturing is reduced and because of additional movements and positioning of the spindle or table, repositioning of the part is virtually eliminated. Because contours and radii, etc., are generated, the requirement for form tools is reduced. NC mills can also do drilling, reaming, etc., which means more jobs can be confined to one machine tool. The NC mill can be utilized for just about any configuration of work, but is most effective on difficult geometric configurations and space curves. (See Fig. A-4.)

The foundation of the NCMT selection process is to assess the present and anticipated workload of each facility. An in-depth workmix evaluation will identify those piece-parts that best lend themselves to manufacture with NC. The results of such a study will reveal the manufacturing processes and characteristics encountered which will provide information for a selection of the appropriate NCMT (i.e., mill, lathe, etc.). Unless a work-mix study is performed, selection of the proper NCMT would be virtually impossible.

Acquisition of the NCMT will result in a capital investment. Therefore, it must remain productive for a period of years. Constant productivity of the NCMT will depend in part on its capability to accept varied workloads. Therefore, as a first step, machine capability must be viewed as to future workloads and not limited to the immediate needs of an existing workload. The second step in the selection process is to evaluate those optional equipments that will enhance the flexibility and capabilities of the NCMT. A case in point would be to have a facility where extensive sheet metal operations would be performed. From the work-mix analysis it has been determined that an NC punch press would result in a substantial savings in punching operations; however, a re-evaluation of the sheet metal shop output revealed a number of jobs that could also be performed by the NCMT with the addition of an optional laser burning accessory. The benefits become immediately obvious: increased utilization through continued productivity, and significantly decreased operational costs by loading two distinct types of operations onto a single machine unit. Optional equipment such as increased horsepower can in most instances contribute significantly to increased production, and thereby reduce costs. However, caution should be exercised to avoid the purchase of options that might result in a high cost NCMT with no appreciable performance advantage. Optional features added to the basic NC machine can increase the total cost by factor of up to two

or more; therefore, care must be taken not to overbuy equipment that cannot be fully utilized.

(a) The first option which presents itself after establishing the NCMT type and size is horsepower. NC makes it possible to optimize all work forces. High slide speeds of 600 inches per minute (IPM) can be accurately controlled, chip cutting can be controlled to the outer limits of the cutting tool. It is, therefore, possible to make better use of high horsepower, but the ease with which NC can make multiple passes results in producing the same work in less time with lower horsepower. Present machine technology is capable of spindle speeds of up to 40,000 RPM with table feed rates ranging from 600 to 1,000 IPM. The higher horsepower NCMT requires more strength and rigidity in the basic machine structure and results in higher hardware costs. Requirements must be critically analyzed to determine if sufficient justification exists for specifying the higher horsepower ratings. Widely varied workloads preclude an all-encompassing guideline to assess horsepower requirements. Horsepower requirements can best be determined after the completion of an in-depth study of parts to be machined.

(b) One of the greatest advantages of the NCMT is the practical application of tool changing devices. An excerpt from a report to Congress by the Comptroller General of the United States, dated June 22, 1975, states: "An automatic tool changer may add 20 to 50,000 dollars to the cost of an NCMT. It may also reduce floor-to-floor machining time significantly (up to 40 percent) when compared with a manual system and should therefore be carefully considered." If the machining process requires a utilization of multiple cutting tools, tool changers should be considered as a desirable option. At this writing three basic types of automatic tool changers are offered as optional equipment. The Turret Toolchanger is the simplest and the least expensive. Its disadvantages are limited tooling capacity and tool interference. Interference is a common problem. The distinct advantage is, of course, the attractive cost factor. A second type, the Sequential Access is a magazine loaded changer. The advantages of this change are a very fast access time, and no requirement for code rings, keys, or selection of specific pockets in the magazine. A disadvantage is no-recall of tools without going through an entire selection cycle. The third system, a Random Access Changer allows instant recall of a tool at any time for reuse in the same program. Numbered pockets reduce the amount of tooling required for the machining cycle. A distinct disadvantage is the increased chance for error as the result of the misplaced tool in the number/tape-coded tool pockets. If the part being machined is complex in design, random access automatic tool changing has a distinct advantage. Tool changing technology has advanced significantly and new state-of-the-art "quick change" manual systems are being utilized with a measureable degree of success in some sectors of industry. Manual tool changing requires physical manipulation of cutting tools in and out of the NCMT by an individual.

Physical and mental fatigue of the operator increase the likelihood of tooling errors resulting in scrapped parts and/or a costly collision. Automatic tool changers virtually eliminate erroneous tool selection resulting from mental and/or physical fatigue, therefore, a tool changer is a desirable option and should be strongly considered. (See Fig. A-5.)

(c) Indexers and/or Rotary tables in many circumstances are desirable accessories. The function of these accessories is to present the workpiece to the cutting tool through the machining process. The simplest design will index the table to move in four 90 degree increments. Tables and Indexers with 360,000 increments are available and should be considered when complex angles exist on the workpiece; a disadvantage being the higher cost for both NCMT machine and control unit when selecting the higher indexing positioners. Maintenance, programming difficulties, lower tolerance of cutting forces, etc. make the high increment indexer an option for which good justification must exist. In most manufacturing processes the four 90 degree indexer will perform the intended function, that of automatically re-orienting the workpiece to the spindle without refixturing or operator intervention. (See Fig. A-6.)

(d) Spindle speeds for NC will have the same range as conventional, except that more increments are required. The optimum is Infinitely Variable Speed. This option is especially valuable on NC lathes. In some lathe operations it is desirable to change spindle speeds without withdrawing the cutting tool. A conventional multiple shift would pose a problem in that a shift would require a feed hold, spindle stop, or both. If this action cannot be tolerated then infinitely variable speed becomes a desirable option.

(e) Spindle nose specifications for NCMT do not differ from those of their conventional counterparts except when it is desired to identify a spindle nose configuration to accommodate a particular set of ancillary tooling. When possible, a spindle nose configuration should be specified which would utilize existing spindle tooling to avoid excessive tooling costs through duplication.

Many NCMT accessories are standard with some manufacturers and optional with other tool builders. If the requirement exists to include or delete the accessory, instructions should be clearly stated in the purchase specification. The most common items are: way covers, chip conveyors, splash guards, automatic bar feed, air actuated chucks, tail stocks, mist and flood coolant jets, automatic draw bar, and work lights.

The information outlined in the preceding pages might lead the reader to draw a conclusion that a standardization of NCMT would eliminate most or all acquisition problems. An experimental study of varied facilities

and the diverse NCMT requirements will reveal that standardization is not feasible in the present state-of-the-arts of machine technology. Standardization, though utopian at present, lies within the realm of future possibility, but will develop as a natural phenomena of advancing design technology. At this time there exists conclusive evidence rendering standardization of NCMT not economically feasible.

### 3. BASIC NOMENCLATURE OF THE NCMT.

Basic nomenclature of the NCMT would be: base or bed, column base mountings, saddle support, column and a saddle. Importance of these basic components suggest that some elementary engineering methods and materials of construction be briefly addressed. NCMT beds, columns, etc., are either fabricated heavy steel weldments or cast from molten iron elements.

a. Construction by weldment, if correctly engineered, can provide adequate rigidity for NC machining operations. However, calculations should prove out a static and dynamic stiffness modulus equal to or exceed that of a similar cast iron structure.

b. Static and dynamic stiffness in both column and bed must be sufficient to control distortion and reduce vibrations that will result in cutting tool chatter. NCMT design should be such that the upper or top weight is reduced proportionately with the bed weight to enhance dynamic characteristics. These characteristics are particularly critical in milling and boring machine tools. The table supports the workpiece and positions it to the cutting tool preparatory to the machining operation. Travel of the table is in the X & Y axes throughout the machining process. The saddle, table, and workpiece must be fully supported by the bed through the full range of travel to eliminate overhang and tool deflection.

c. Slideways which support the saddle and table serve as guideways for the movable machine members. The ways are hardened and precision ground to extreme close tolerances. Many machine manufactures bond the way surfaces with non-metallic compounds such as Turcite. Turcite is a teflon derivative with an extremely low coefficient of friction. This reduces stick/slip and increases the capability of the servo system to achieve extremely close positioning accuracy.

d. Steel materials used in construction must be of such quality that good damping properties are inherent. The damping capacity or the ability to absorb vibration must be high. There exists specific types of iron materials that lend themselves to machine tool construction. High pearlite irons, such as Meehanite, or nodular iron, have the highest damping capacity of all engineering metals; this accounts for the common selection of cast iron for machinery beds, columns, and housings.

e. Meehanite is the name of numerous cast irons, each having different combinations of mechanical and engineering properties. Four general classification types are produced: (1) general engineering, (2) heat resisting, (3) wear resisting, and (4) corrosion resisting. Tensile strengths vary from 25,000 to 55,000 PSI, and, when oil quenched and tempered, a strength of 75,000 PSI can be obtained. Malleable-iron is a mixture of iron and carbon including small amounts of silicone, manganese, phosphorous and sulfur, which, after being cast, is converted by heat treatment, into a matrix of ferrite containing nodules of tempered carbon. The ordinary malleable iron grade has a tensile strength from 50,000 to 55,000 PSI. Pearlite malleable irons develop tensile strength upwards of 85,000 PSI. Machinery castings are outstanding applications of these elements.

All castings for beds, saddles and columns must be free of defects (i.e., sandpits, cracks, however minute and scale). There must be no process such as welding, peening, plugging or filling with solders or metallic pastes to reclaim a defective casting. The extreme stresses generated from heavy loads incurred during rapid positioning, cutting, and rapid traverse can develop a minor defect into a major fault.

Molten and cast iron beds, saddles and columns are cast individually in one (1) piece, then precision machined to very close tolerances and fitted together as an integral working unit to achieve the greatest degree of accuracy at the tool point with high metal removal rates. (See Fig. A-7.)

The NCMT alignment accuracy and cutting accuracy are in direct proportion to static stiffness. Moreover, the maximum chip removal rate and resulting surface finish are related to the machines dynamic stiffness. Tool force upon contact with the work piece and continuing throughout the cut exerts heavy loads on the various axes of the machine tool. (See Fig. A-8.)

f. A controversial method of updating an existing NC machining system is to retrofit the existing NCMT. Existing NCMT may, under special circumstances, be retrofitted in such a manner that substantial savings in monetary outlay can be realized. Extremely long lead times for delivery coupled with the high cost of materials can, in some instances, justify retrofitting. The extra heavy bed castings of older machines are very valuable since increases in raw materials costs can result in a much higher price for a comparable bed casting on a new NCMT acquisition.

Special purpose machines, such as those required in airframe construction and aerospace programs, are especially good candidates for retrofit. NCMT such as planer mills, spar mills, and traveling column contouring mills are prime examples. An appropriate retrofit will include inspection of all ball loaded lead screws, drive screws, and gear

trains, if an economically sound investment is to be achieved. The rapid advance, technologically, in the state of the arts for NCMT of the job shop variety requires a very strong justification before retrofit, as opposed to a new acquisition is to be considered.

The retrofit investment should be proposed on a project basis. The project must be outlined for all requirements and benefits related to the economic life of the project and included in the investment proposal. Machine tool builders or contractor analysis of the project will be established and implemented by specifications of the proposed retrofit of the NCMT and related software.

An NCMT candidate of the job shop variety under consideration for retrofit must be viewed as to condition, age and capability. NCMT beyond a vintage of ten years should not be considered for retrofit projects. Machines being retrofitted must be certified as a model still in production with availability of repair parts. Retrofitting will be justified using the same criteria as would be used on a new NCMT acquisition. Conventional machine tools must not under any circumstances be considered for retrofit to an NC system. Primary reasons being: (1) the rigidity and tool deflection factor, and (2) a matter of positioning accuracy. NC machining requires an extremely rigid machine base structure to minimize tool deflection and the resulting chatter. The conventional machine tool base, generally, is not designed with the weight and rigidity factors required of the NC machining process. Retrofitting remains a controversial subject as a means of updating an NCMT system. It can be concluded, however, that special purpose NCMT as opposed to job shop NCMT are the most likely candidates to be economically justified for retrofit.

#### 4. TOOLING

This section is devoted to the subject of peripheral tooling requirements to support the NCMT. The objectives remain identical to those identified in the preceding section. Tooling is a generalized term that encompasses three separate, but highly integrated elements. The three elements are: (1) Fixture Tooling, (2) Cutting Tool Holders, and (3) Cutting Tools. The unique functions of each element necessitate individual discussion.

a. Fixture tooling can best be described as that member of the tooling family that physically holds the workpiece on the NCMT during the machining operation. The area of fixture tooling offers a great cost reduction potential due to the fact that NCMT does not require complex and expensive fixturing.

The ultimate fixture is one that can be dismantled after each job and rearranged to do another -- a universal fixture. Such a fixture could be a four-sided box or tower that is mounted on the work table of an NCMT,

or the fixture might be one in the configuration of a picture frame. The objectives being design simplicity to reduce tooling cost and multiple workpiece loading to minimize time consumed for change-over of work pieces. The type fixture described above is particularly effective on NCMT that presents the cutting tool horizontally to the workpiece. Such a fixture, with little or no modification, could be utilized on conventional machines; again cutting tooling costs through reduced tooling inventory. (See Fig. A-9.)

A second basic type fixture could be described as modular, or in units constructed semi-standardized in configuration, but with flexibility enough to hold a variety of workpieces. The fixture is a rectangle of steel plate, ground smooth, drilled, jig-bored, and tapped in rectangular coordinates to accommodate locating pins, dowells, and holding clamps. When the part run has been completed the pins, dowells, etc. are removed and the blank plate can then be stored on edge to reduce storage space. The NC system should be analyzed to determine fixture tooling design that will maximize interchangeability between NCMT. (See Fig. A-10.)

After assembly and prior to delivery in the machine shop area for use, the fixture will be assigned a unique code number for identification purposes, photographed, and filed by workpiece or part number for future setup reference. The tooling code number and all pertinent setup information will be then recorded on a file card and made a permanent part of the engineering package.

Fixture sub-bases described in the prior paragraphs may be purchased from various machine tool builders, however, in-house design and fabrication are recommended to reduce acquisition costs and increase capability for interchange between NCMT. Basic fixture design and fabrication should be completed well in advance of the anticipated NCMT delivery date to insure immediate operational capability. Generally, NCMT fixturing design is simple and is nominally expensive when compared with conventional machine tool fixturing.

b. The tooling section, for efficiency, should be located in or adjacent to the actual shop area. All NC tooling operations such as: fixture design, fixture buildup, cutter, tooling and fixture storage, and tool re-grind facilities will originate in this section. Upon completion of a job the tools will be returned to this area for disassembly, cleaning, inspection, repair as needed, and stored. The personnel responsible for the tooling section must be highly skilled individuals. They must be skilled in: (1) fixture tooling and design, (2) fixture tooling buildup, and (3) cutting tool geometry. An individual of Journeyman Grade Machinist or a Tool & Die Machinist would be an ideal candidate.



Centralization of tooling can most easily and effectively be accomplished by utilizing a combination of modular cabinets as tool cribs. Efficient tool storage systems are those which are systematically constructed and capable of being enlarged as required with little or no wasted space. In many instances modular cabinet systems have reduced floor space requirements of up to 56% and 100+% in waiting time for tooling. Modular cabinet systems put everything in sight and compared to traditional shelving systems, store more in less height, plus, fully loaded cabinets are easily moved into new arrangements.

A recommendation can be made that each facility utilize the no-cost, no-obligation studies offered by various manufacturers to determine modular storage cabinet requirements and layout configuration. (See Fig. A-11.)

The tool crib will contain anywhere from hundreds to thousands of different types and dimensions of cutters for all NCMT. The NC programmer must select the type and size of tool required for each specific machining operation. The problem lies in making sure that the tool designation he uses is recognizable in the tool room and to the NCMT operator. To solve this problem the machining facilities will be required to adopt a standardized tool identification system. (Tools and tool parts are not standardized among suppliers, so a customized system within the facility is the most practical solution.) Such a system will utilize a series of alphanumeric characters, each of which identifies some characteristic of the tool.

An established system will serve to eliminate confusion and misunderstanding that result from time consuming verbal conversations aimed at finding out exactly what tool is required. This in turn will result in faster, more efficient tool room operation and virtually eliminate work-piece rejects caused by tooling errors. The second function of the system is inventory control. Tool inventory control will ensure that costly machine downtime will virtually be eliminated due to lack of the specific tool to perform a special operation. A catalog with proper tool inventory and tool identification will greatly assist the programmer, serving as a ready reference, thus, reducing program time and cost. (See Fig. A-12.)

b. Cutting tool holders or collets are that part of tooling which retain the cutting tool within the spindle during the machining operation. This type of tooling is purchased at the time the NCMT is purchased and will approximate 10% of the NCMT purchase price. Significant dollar savings can be realized in this area of tooling through the adoption of a commonality in headstock spindle tapers for the NCMT. The present trend in industry and machine tool builders is to adopt the "V Flange taper" as a standard taper for tool holders and NCMT headstock spindles. The National Machine Tool Builders' Association (NMTBA), American National Standards (ANSI), and Caterpillar Tractor (CAT) have

endorsed the "V Flange taper". (See Fig. A-13.) The advantages are reduced tooling costs and interchangeability of ancilliary tooling between NCMT. A possible disadvantage would be a future change in the state of the arts of NCMT cutting tool application. Most metal working facilities presently using NCMT will find that any changes or modifications to the now existing tooling standards will be a gradual process and geared to the expansion of the NC machining capabilities.

c. The third member of the tooling family is the cutting tool. Cutting tools perform the actual material removal from the raw stock to form the finished part. Cutter tooling is designed to perform specific functions; therefore, the selection of proper tooling becomes a very important segment of the programmer's responsibility.

Cutter tooling is an extremely important facet; however, it is often the most neglected, especially by facilities entering NC for the first time. Extensive studies are often made in order to select the proper \$300,000 NCMT backed up by a \$200,000 computer, but equipped with an inadequate \$50 cutting tool. This could well become a half million dollar's worth of headache. Therefore, a working relationship between designer, programmer, setup man, and NCMT operator must exist.

By the very nature of NC, the success or failure of the workpiece program rests with the programmer. He must know the capabilities of the NCMT. To effectively program, he must have the same confidence in tooling policies and standards as those concerning the NCMT and computer software. Therefore, it is a must to have a set of cutting tool dimensional standards and enforce a policy that all cutting tools (except specials) be purchased to these standards. No single best approach exists for establishing standards for NC users. It is only necessary for each user to establish a firm procedure that best satisfies the needs of the facility. But it should be reiterated that with any successful NC installation, an acceptable procedure and policy will have to be established and followed. Rigid policies should be established for tool re-grinding and tool setting. The policies must be understood and adhered to by the entire manufacturing chain and any policy change must be immediately announced and in such a way that it is fully understood by all.

Cutting tools are formed from high speed tool steels or disposable inserts made of carbide, aluminum oxides, tungsten, and ceramics. The selection of tooling depends in part on the raw material machining operation, and the finish required. Nearly every area of metal cutting has benefited from the wide spread and growing use of inserts. But inserts have proven to be particularly effective on NCMT because their high performance is a good match for the higher capability of NCMT.

NCMT make better use of inserts because they generally have more horsepower and rigidity and can take advantage of the ability of the insert to operate at much higher feeds and speeds. Inserts make for more effective use of NCMT because they allow high metal removal rates and reduce tool change downtime. Inserts enable the NCMT, with its generally greater burden rate, to operate at a very high level of profitability. Cutters formed of high speed tool steels will continue to be utilized for specific machining operations; however, insert tooling should be specified by the programmer as often as possible to enhance productivity. (See Fig. A-14.)

A sound policy to follow in NC machining is to use the shortest and most rigid cutting tool that can be applied to the job. More loss of accuracy on NCMT comes from twist drills that walk off center because of improperly ground points; from long weak drill shanks that bend and wander; and from long end mills that flex and subsequently machine out of tolerance, than from any other source. Thus, cutting tool standards should concentrate on short, rigid tools.

The cutter size or sizes to be used should be noted on a tooling drawing. The basic objective is to have a written record of everything pertaining to the particular program. (See Fig. A-15.)

The curse of excessive paperwork is recognized, and the idea is not to encourage empire building and a paperwork deluge, but rather to have available the necessary data so that three years in the future when the part again comes up for production it will not be necessary to go back and relearn everything. Obviously the extent to which records are kept will depend on many factors, including the number of people involved. But if adequate records prevent an oversized cutter from being employed, they are worth the effort, especially when a cutter could remove too much stock from an expensive casting or could collide with a holding clamp or fixture.

As for tool material and geometry, solution of tool application problems is the same whether the machining is manually or numerically controlled. If a high-cobalt, high-helix end mill works best on a specific material conventionally, use it on the NCMT.

Finally, do not sacrifice quality for price. Generally speaking, a high quality tool provides a greater economic advantage on an NCMT than a conventional machine for three reasons: (1) The NCMT machine is making chips more of the time, (2) its inherent features allow faster feed rates, (3) its greater cost means a higher hourly charge.

## 5. CONCLUSION

A major objective of the NC/CAM Study was to develop and enforce a policy of standardization of NC hardware within the depot maintenance system. There is conclusive evidence that standardization of NCMT is not economically feasible due to the varied workload within the depot system. A commonality in NCMT could be achieved by adopting a standard spindle-nose taper, thus, allowing interchangeability of ancillary tooling (i.e. tool holders, collets, etc.).

The addition of optional equipment(s) will enhance productivity of the NCMT. An example would be an automatic tool changer which in many cases has shown a productivity increase of up to 40%\* when compared with a manual system.

An in-depth work-mix study will determine the type of NCMT that will best suit the needs of the individual depot. Unless a work-mix study is performed, NCMT selection would be virtually impossible. Significant cost savings will be realized in the area of fixture tooling. NCMT does not require complex and expensive fixture tooling.

The rapid advance in the state-of-the-arts renders retrofitting NCMT of job shop type not economically feasible. Conventional machinery should never be considered for retrofit.

Ancillary tooling (tool holders and cutting tools) will require special storage areas and maintained by skilled attendants.

An in-depth work-mix study for each depot in DESCOM was performed by a skilled team to determine the feasibility of implementing the NC concept. The results were analyzed mathematically to obtain a productivity increase ratio and as a basis for the recommendation for specific types of NCMT for each depot. The conclusion was that with the addition of NCMT the average productivity increase would be 3 to 1 when compared with the present conventional method of machining.

Mechanics of The Program Tape

(a) The NC machining tape is based on the Cartesian system of rectangular coordinates.

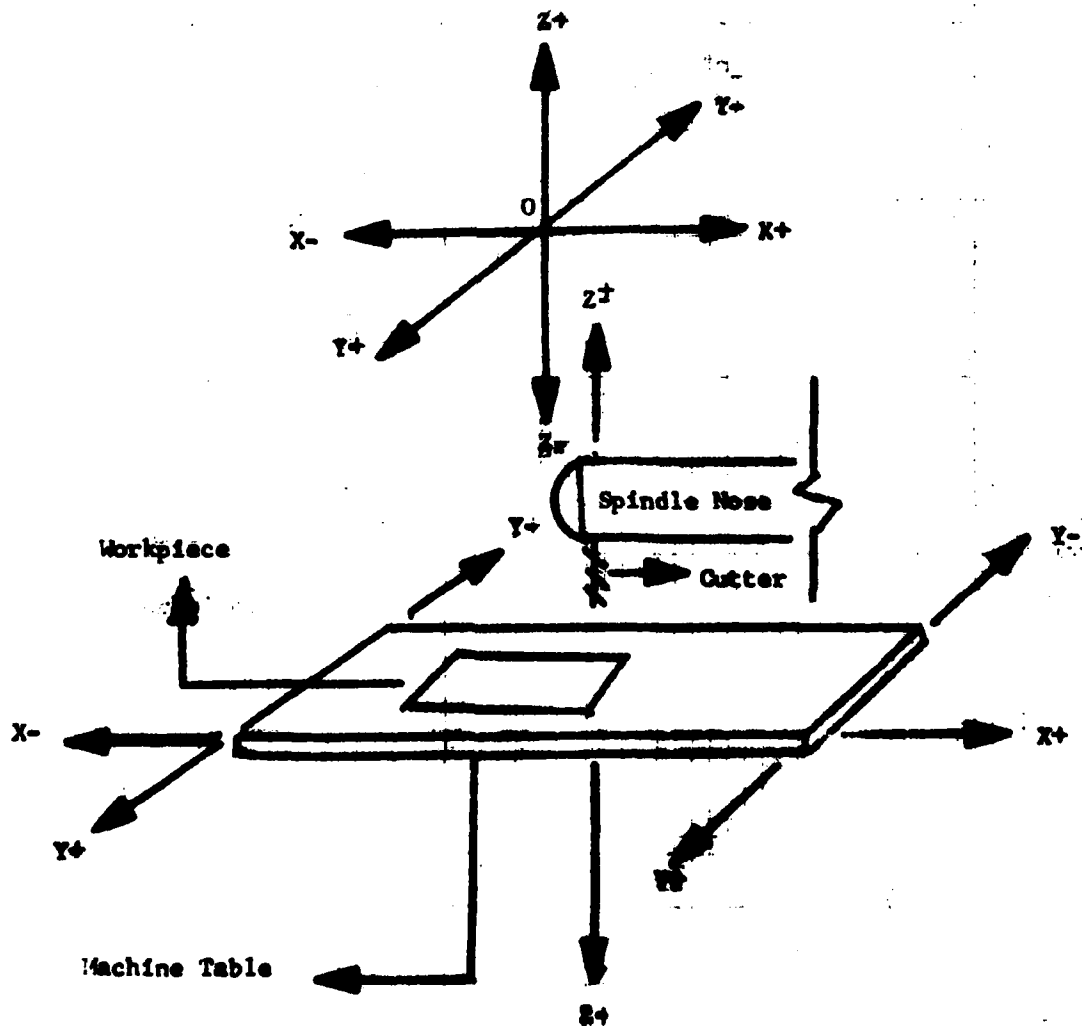
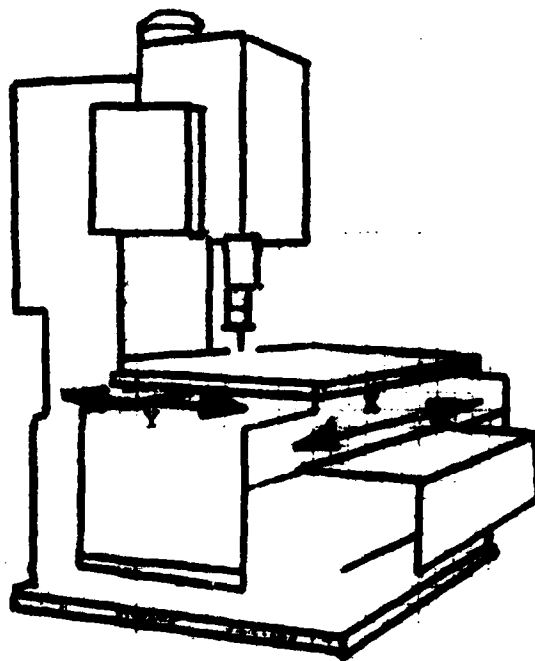
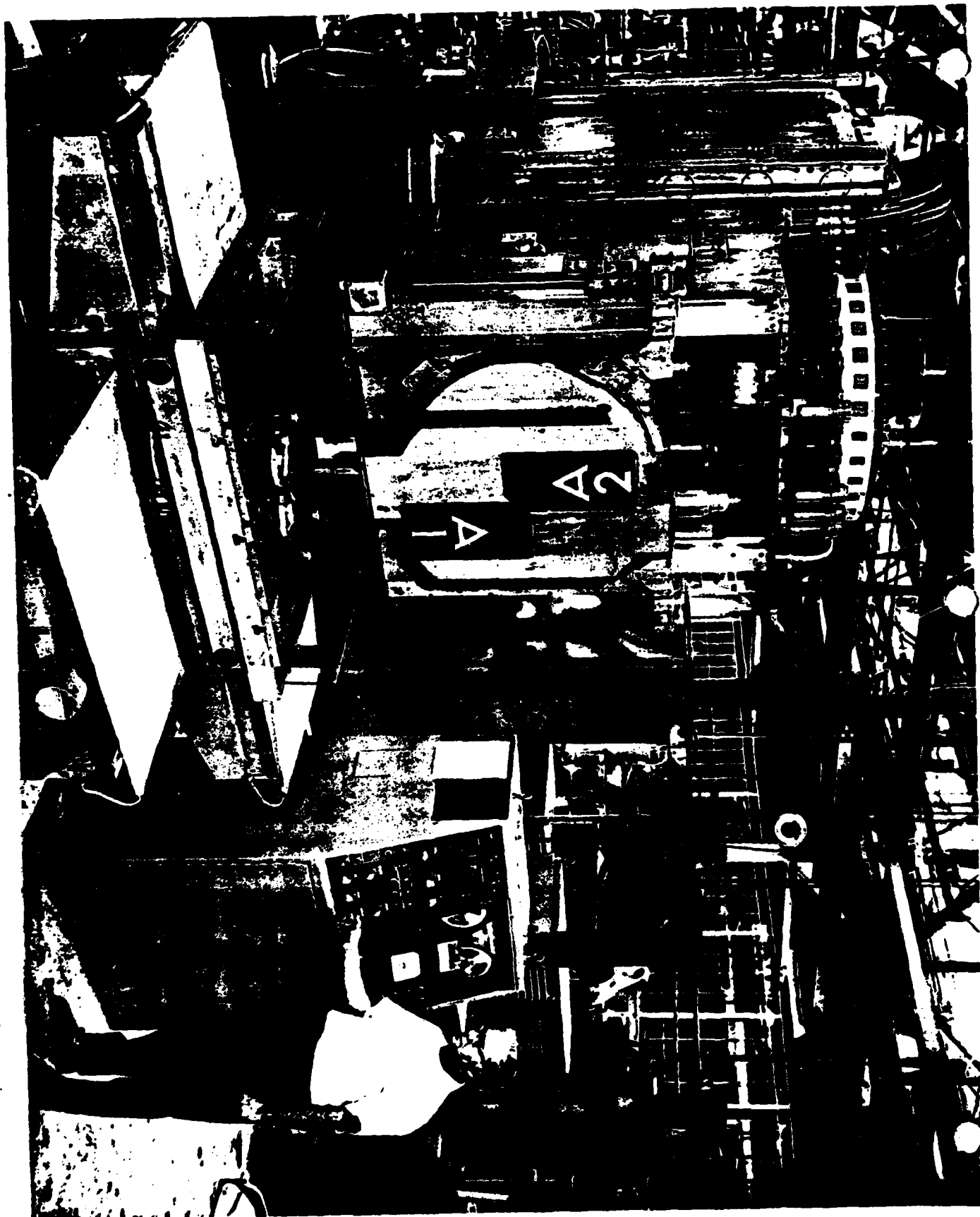


Figure A-1. Schematic sketch of machine table and cutter mechanics during a typical 3 axis machining operation.





**Figure A-2 (Sketch) Two axis, single spindle tape controlled drilling machine. X and Y axis direction of travel noted by horizontal and lateral arrows.**



(Photo.) Drilling Machine



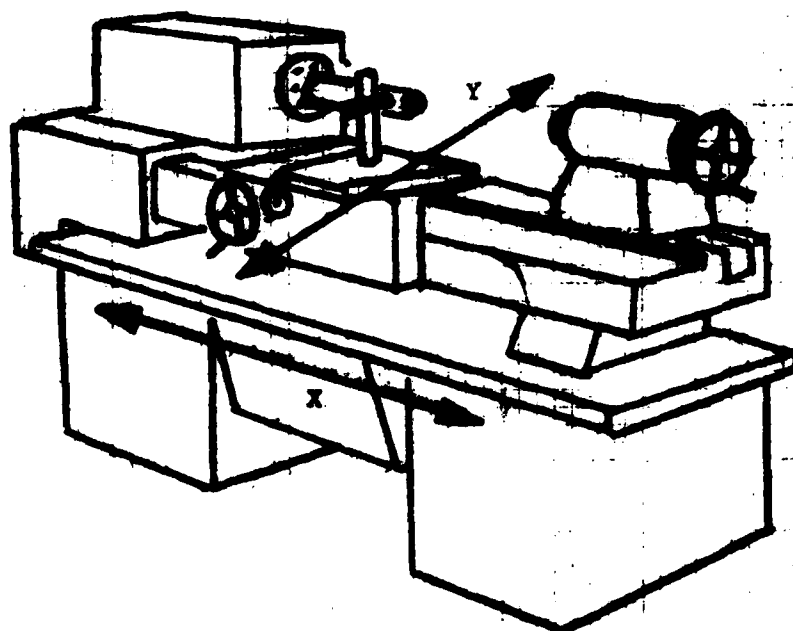
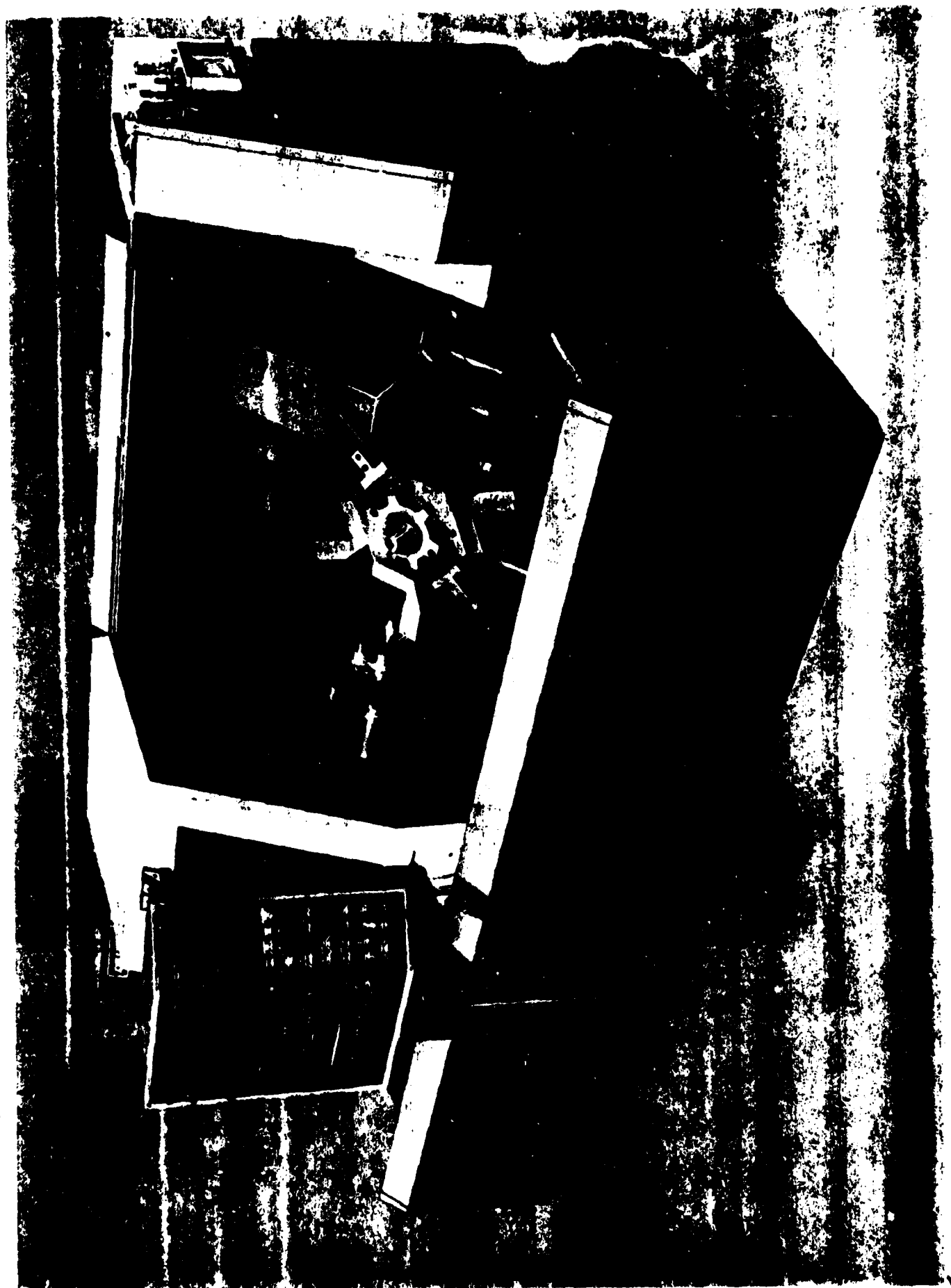


Figure A-3 (Sketch) Two axes, single tool tape controlled lathe. X and Y axis direction of travel noted by horizontal and lateral arrows.



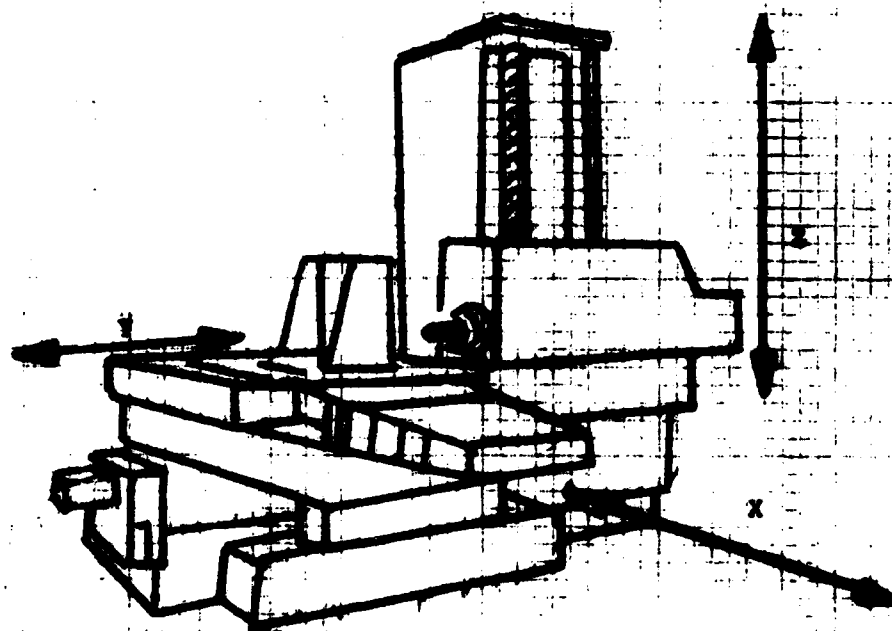


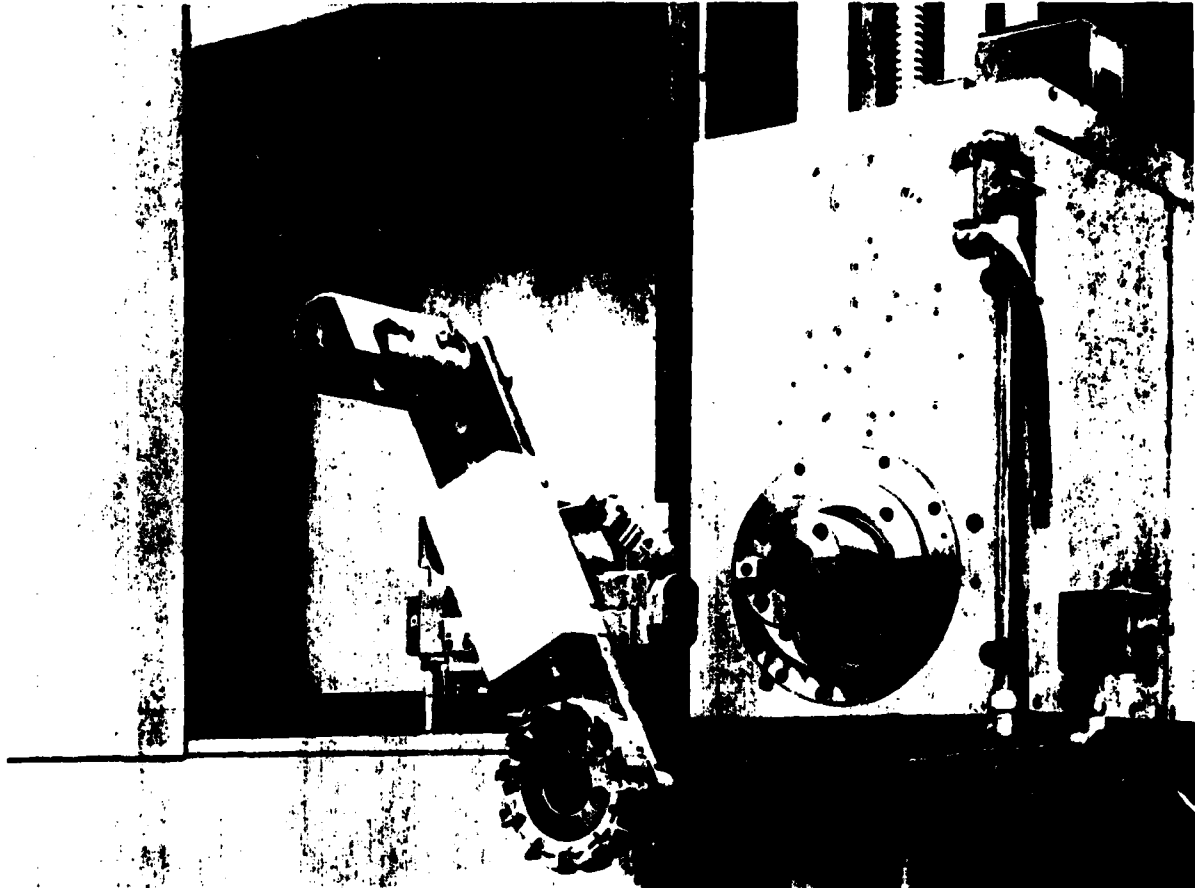
Figure A-4 (Sketch) Three axis, single tool tape controlled milling machine. X, Y, and Z axis direction of travel noted by horizontal, lateral, and perpendicular arrows.



Figure A-4 (Photograph)  
Milling Machine

CHART 6A

# OPTIONAL AUTOMATIC TOOLCHANGER



An increasing number of metalworking plants today are recognizing the value of automatic tool changing as an aid in maintaining or lowering manufacturing cost levels. Setup time between parts and changeover time between jobs is machine idle time that has traditionally been a prime target for cost-saving programs. On large machines with heavy tooling, automatic tool changing unquestionably saves time and operator effort. Furthermore, an automatic toolchanger combined with work-handling devices and alternate work stations creates the opportunity for really significant time savings on each job.

toolchangers are rugged accessories designed to handle the type of tooling typically used on large, heavy-duty machine tools.

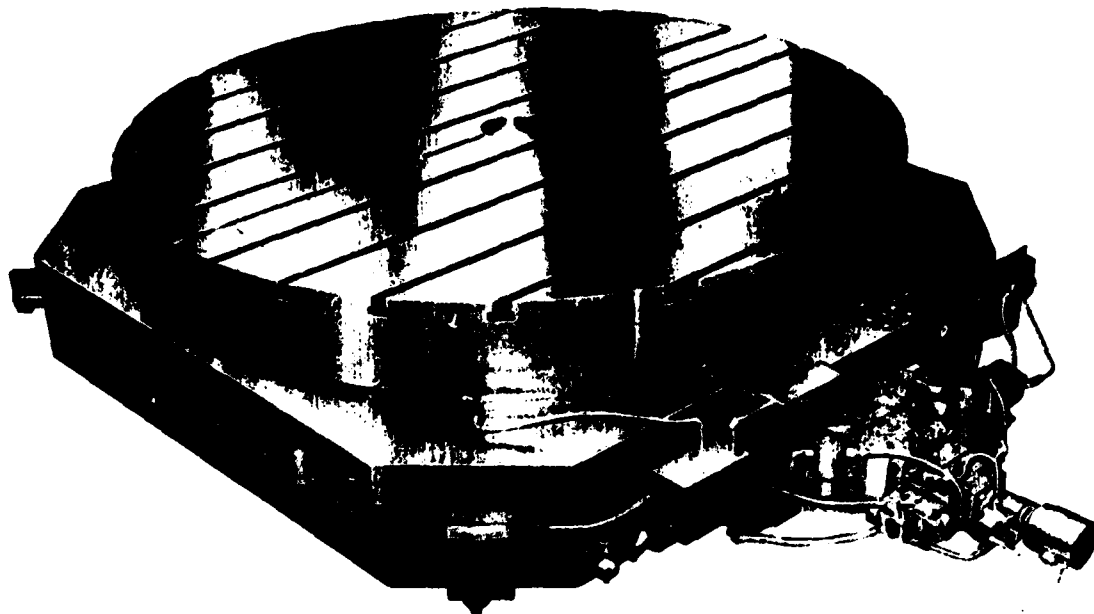
Tool length compensation is an important feature that reduces time usually spent in part setup and programming. Loading the tool data in the CNC 800 control is a fast and simple operation.

Tool lengths can be entered from tape, by keyboard, or by touching the tool tip to the part and entering that data in memory with a single keystroke. With capacity for up to 100 tools that can be 24" long, the automatic toolchanger can store a complete family of tooling, which almost eliminates the need for tooling delays between jobs.

Figure A-5

## SPECIFICATIONS

Capacity	40 to 100 tools
Tool length	up to 24" (610 mm)
Tool diameter	up to 16" (380 mm); tools with block-type cutters can be larger
Tool weight	up to 75 pounds (35 kg)



## Model 360, Numerical Control Hydrostatic Rotary Table

Indexing is completely automatic via tape or manual data input commands.

Accuracy -  $\pm 5$  seconds of accuracy. Rotary Inductosyn scales and a double pinion, wound-up gear box contribute to accurate positioning.

Hydrostatic, preloaded ways and center post create maximum rigidity while machining with power feed.

Power milling feed range from 0-40" (4572mm) per minute through a servo drive.

### Standard Features

Table inscribed to read in half degree increments.

Fixture locating keyway.

Eccentric bushing.

Center bore in plate.

### Optional Features

NumeriRead<sup>®</sup> measuring system-replacement for N/C.

"Stand Alone" milling feeds - .1 to 100" (2 to 2540mm) per min. through an electric servo drive.

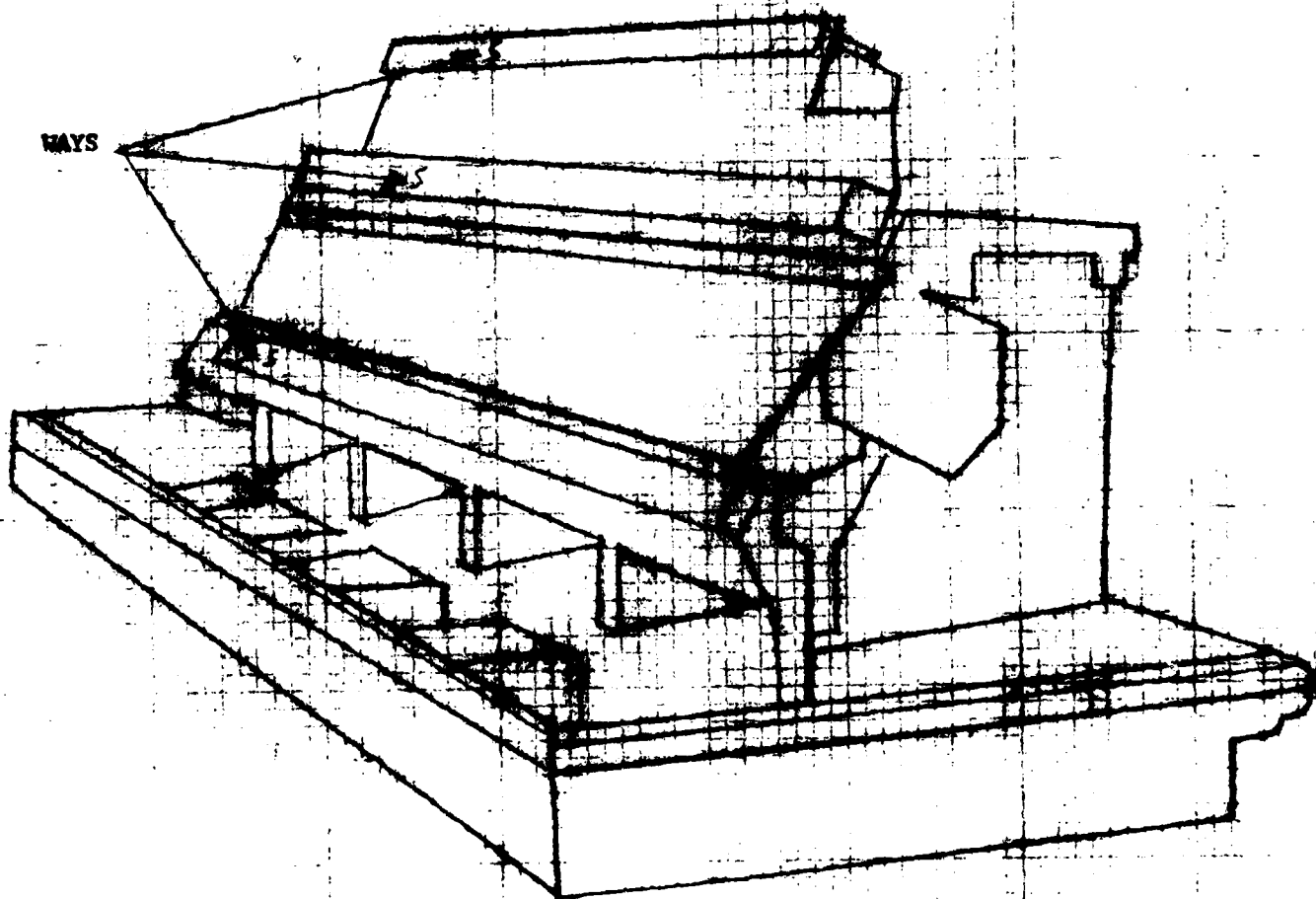
### SPECIFICATIONS:

#### Table Sizes:

Round . . . . .	30" (762) - 120" (3048)
Square . . . . .	30" (762) - 120" (3048)
Rectangular . . . . .	30" x 36" (762 x 914) - 96" x 120" (2438 x 3048)
Overall height . . . . .	16-3/4" (424) - 33" (838)
Load carrying capacity . . . . .	5,000 - 150,000 lbs. (centrally located)

( ) = millimeters

Figure A-6



(Sketch) Figure A-7 Sketch of 1 piece Chucking Lathe bed casting.

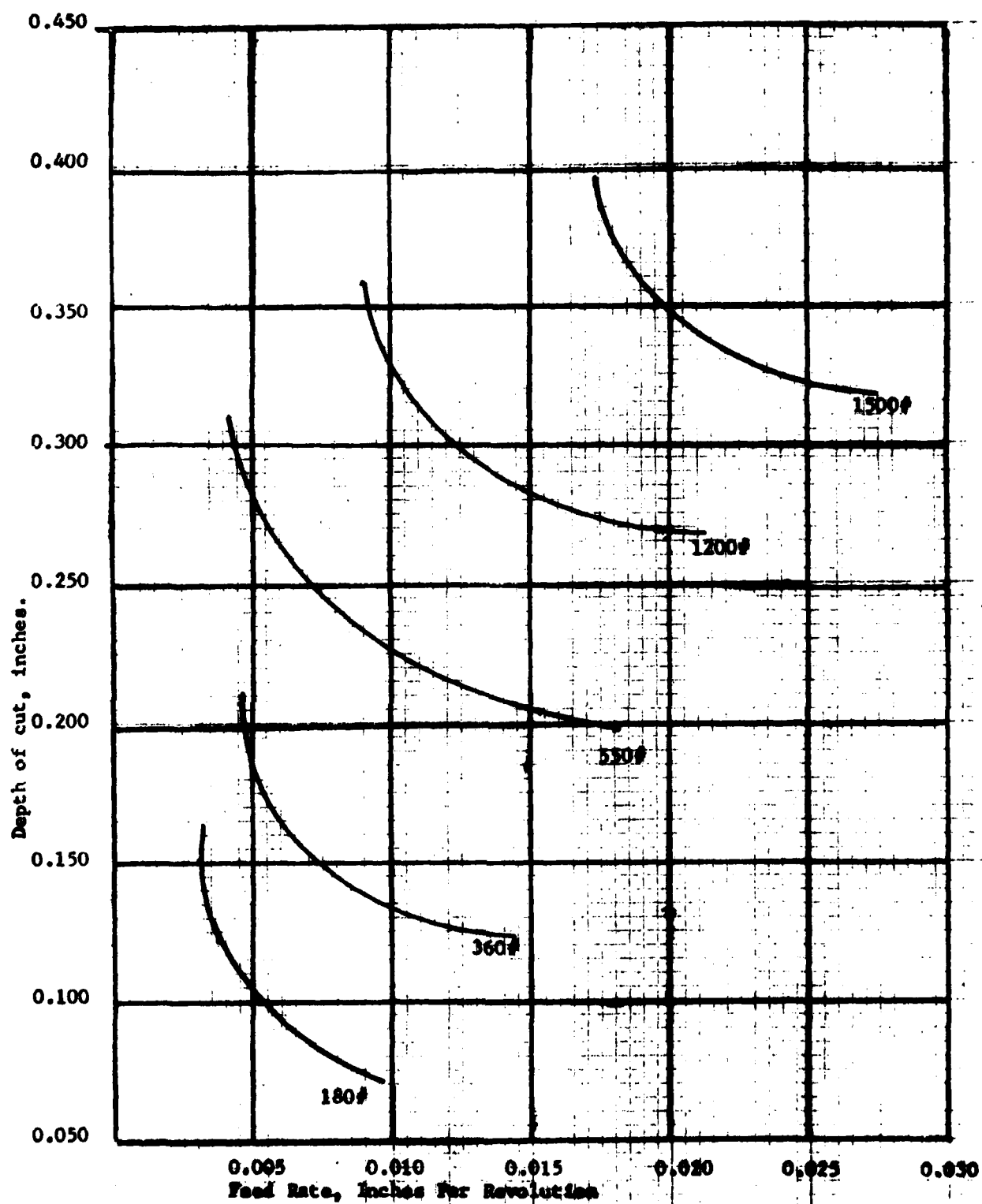


Figure A-8 Forces for various size cuts when turning AISI 4143 steel @ 400 surface feet per minute (SPM)...



# UNIVERSAL FIXTURE

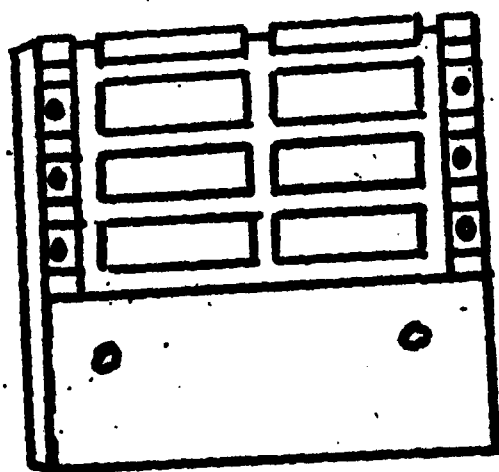
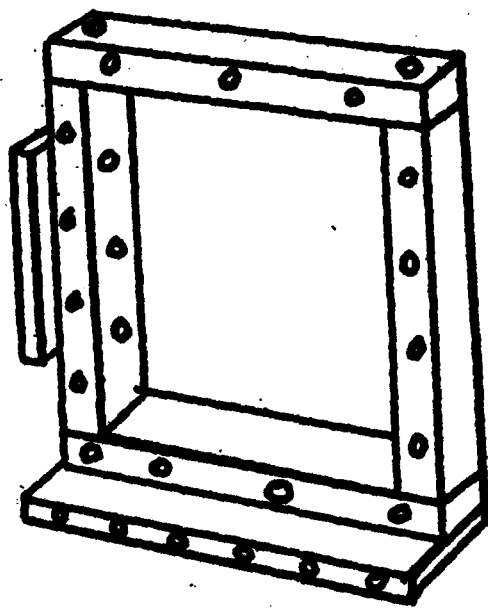


Figure A-9

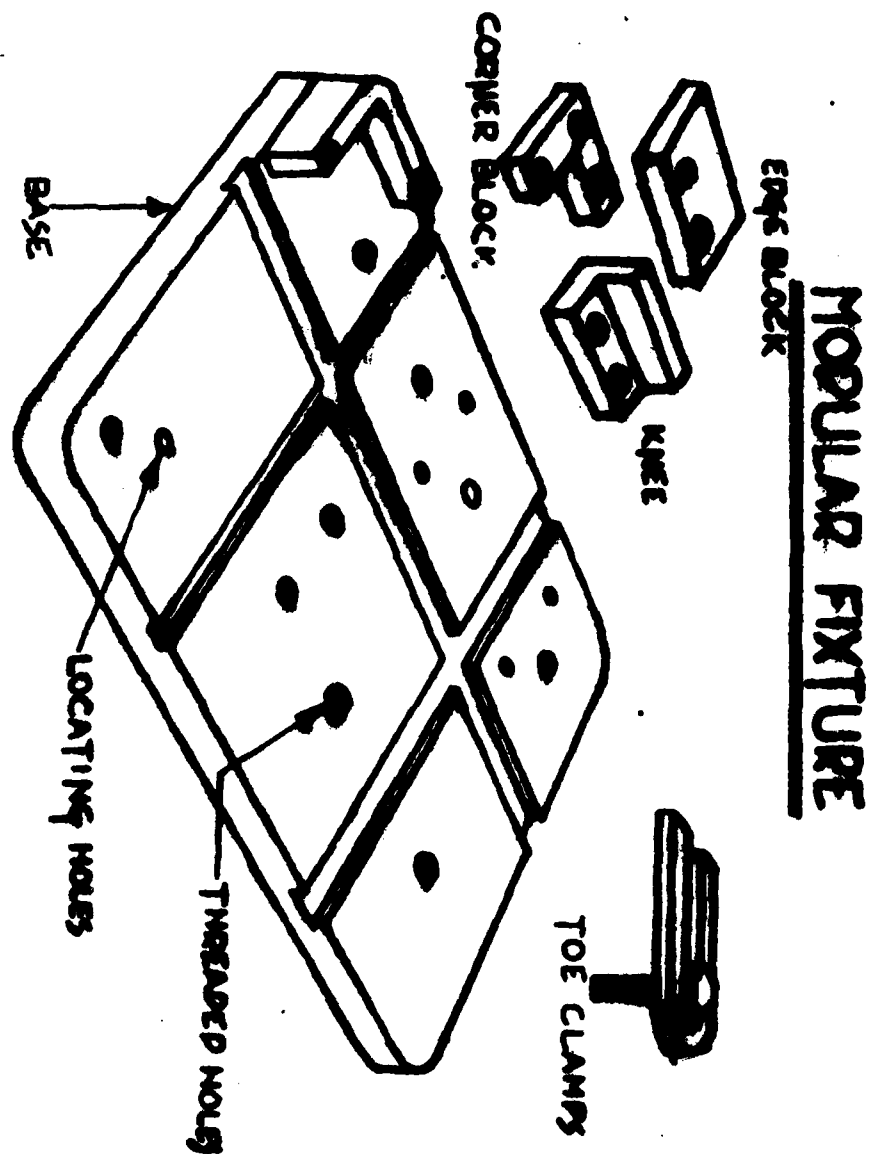


Figure A-10

Reprinted from **FACTORY**

## TOOL CRIB DRAWERS CUT SPACE NEEDS IN HALF

*Corrosion and dust are no longer a problem with the closed storage system. And the crib has a neat uncluttered appearance.*

**T**his file-drawer approach to tool cribs is conserving valuable space at International Business Machine Corp.'s Endicott (N.Y.) plant. The industrial storage cabinets used are neat and efficient, yet take only half the space of any conventional tool crib racks.

Tools and equipment used to be stored on shelf units—some open, some closed. A master location chart, broken down by shelf and cabinet number showed where each item could be found. With this system frequent physical inventory was



**STORAGE-SPACE SAVER:** Every item is within an arm's reach of the tool-crib attendant with these storage cabinets. Thus inventory is fast and simple to take visually, and the long lines outside of the crib are past.

necessary to avoid depletion of any tool. And as operations expanded storage space in the 30x40-ft. crib area was at a premium, and passage aisles became increasingly smaller. Furthermore, humidity, dust, and chip deposit damaged the tools stored in the closed and open shelf system.

Use of the storage cabinets (Vidmar, of Allentown, Pa.) alleviated all of these problems. Tools, parts, and accessories formerly dispersed on the shelves are now neatly and compactly arrayed in king-sized

pull-out drawers. And a smooth top which covers three of the 44-in.-high units acts as the tool crib counter (top photo).

The interchangeable drawers—some weighing nearly 300 pounds—can be easily pulled out to full length without tilting. Large exterior labels identify contents of each drawer (see photos) and interior tags mounted securely on the dividers identify items by style and size.

Since all items are almost within arm's length of the clerk, service is faster, eliminating waiting.



**FLEXIBLE PARTITIONS** in these drawers make it easy to store fixtures and gauges of diverse sizes and shapes. Despite the 275-lb. weight of its contents, the drawer opens all the way without sagging.



**HOLDING HOLES** on an aluminum plate allow IBM to accommodate more than 140 collets in a single drawer. Anchoring the collets in this fashion prevents damage when the drawer is opened.

**Figure A-11**



**PEGS** in drawers permit neat storage of milling cutters. Formerly they were hung on wall peg where they were exposed to dust and rust owing to humidity. Neither is a problem here.

## **NUMERICAL CONTROL MACHINE TOOLING LIST**

## For Machine.

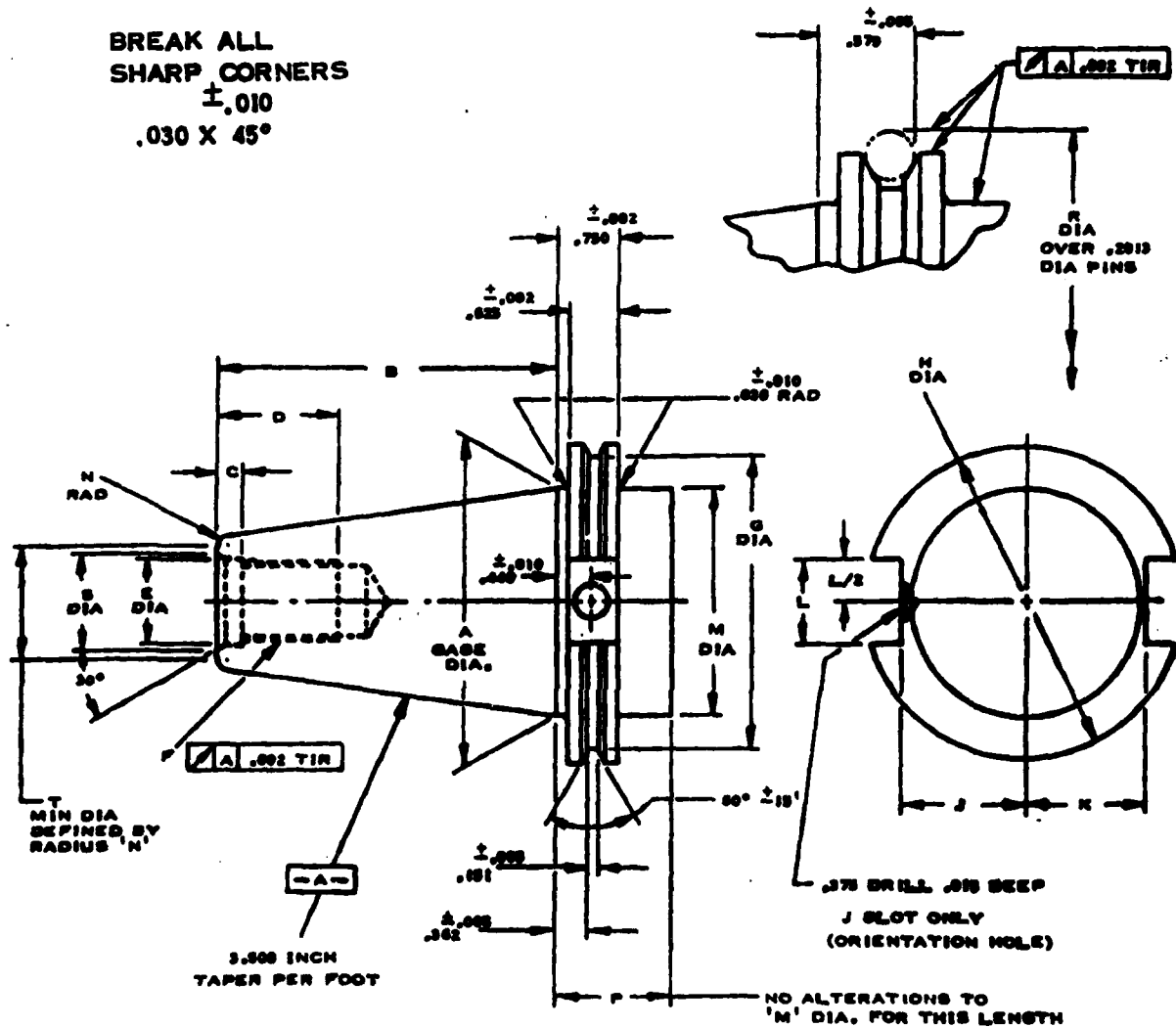
[illegible]

**Figure A-12**

**Courtesy: Balas Tool Co. - A Division  
of Warner-Swasey Machine Tool Builders**



**BREAK ALL  
SHARP CORNERS  
±.010  
.030 X 45°**



S I Z E	$\pm .002$	$\pm .010$	$\pm .010$	$\pm .04$	$\pm .015$ - .000	CLASS 2B THD	$\pm .010$	$\pm .002$	$\pm .000$ - .015	$\pm .000$ - .015	$\pm .010$	$\pm .010$		$\pm .000$	$\pm .002$	$\pm .010$	MIN
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T
30	1.250	1.875	.100	1.00	.516	.500-12	1.531	1.612	.795	.640	.645	1.250	.515 - .000	1.575	2.175	.500	.00
40	2.700	2.467	.100	1.12	.641	.625-11	2.210	2.500	.900	.800	.645	1.700	.500 - .000	1.575	2.500	.750	.00
45	2.250	3.250	.100	1.00	.700	.750-10	2.000	3.125	1.225	1.140	.775	2.250	.500 - .120	1.575	3.415	.500	1.00
50	2.700	4.400	.200	1.75	1.000	1.000-9	3.004	3.375	1.405	1.000	1.400	2.700	.500 - .120	1.575	4.250	1.150	1.50
60	4.250	6.375	.312	2.25	1.250	1.250-7	5.210	5.500	2.225	2.140	1.625	4.250	.120 - .120	1.500	5.000	1.375	2.00

DATE ISSUED: 11-1-72

DATE RECEIVED: 2-1-77

NAME: DESIGN SPEC. FOR V - FLANGE  
TOOL SHANKS AND RETENTION KNOBS

MF 5311

PAGE 1 OF 2

APPROVED BY [Signature]

**Figure A-13**

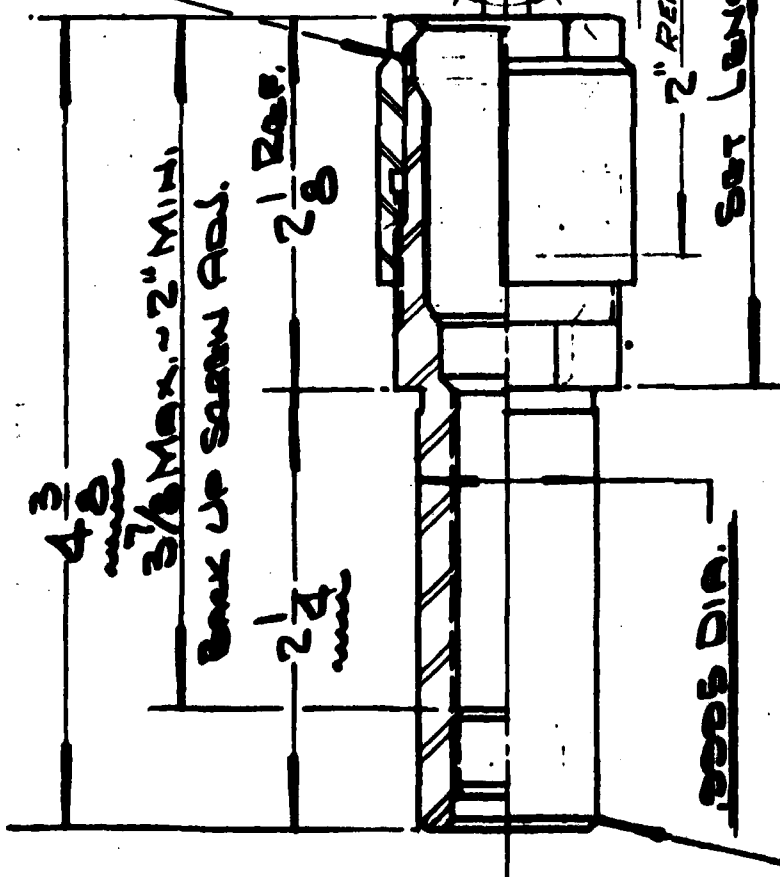
1 0-00-1 2000-1

(Photo.) left bottom, Carbide  
-Oxide insert tooling, right  
center; High Speed Tool Steel  
cutters.



Figure A-14 Cutter Tooling.

BRICKSON DOUBLE ANGLE CENTER  
 1/4 DIA. - (MOOR # 503100013)



#3 CONE DRILL (TRAINING) - H.S.S.  
 CASE # 503100015

BRICKSON SPEC. CENTER CHUCK (MOOR # 183)

CASE #

NOTE:- Due To 3/8-18 I.D. THRO. TOOLS WITH SHANKS OF 1/16 DIA. THRU 1/4 DIA. CENTER BE INSERTED IN CENTER MORE THAN 2"

EST LENGTH	3.13	MAX 2.19	MIN 2.50	BASIC
PROC.	DATE	LONG 2-10-70	CHANGES	USED ON MONARCH 1/2 BATCHES
DES.	DATE	DATE	BY	DESCRIPTION
LONG 10-16-70				TOOL NAME CENTER DRILL
				TOOL NO. 10

Figure A-15

TOOL GROUP NO. 0 TO 50  
TOOL NAME CENTER DRILL  
MACHINE NAME MORGAN

[illegible]



## Appendix B

### NC SOFTWARE

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## Appendix B

### NC SOFTWARE

#### 1. Introduction.

The term software describes computer programs, which are not an end in themselves. Initially that meant compilers and assemblers used to translate source programs prepared in a programming language into a machine tool language and operating programs (loaders, schedulers, etc.) for batch processing computers. In recent years, programmable on-line devices such as intelligent terminals and softwired controllers have become very popular. They require executive programs (operating software) which allows interactive operation. Computer programs for very specific tasks, that are needed by many users are often organized into "Software Libraries."

The processors and post processors for parts programming languages are the earliest examples of software in the NC field. Intelligent terminals with a substantial amount of operating software made their entry into the world of design and manufacturing in the early 1970's in connection with "CAD/CAM" or "Interactive Graphics" systems. At present, several commercial vendors offer libraries of analysis programs (finite element analysis etc.) for immediate checkout of contemplated designs in connection with their Interactive Graphics systems.

Softwired controllers contain a digital computer with memory. Computer memory is used to store the executive program and the information from a control tape. The executive program creates the structured environment for the processing of machine control data and thus is the counterpart of the hardwired logic of other controllers. The operation of the softwired controller is different from and smoother than hardwired control in that the entire control tape is loaded into the computer memory prior to the machining process. Hardwired controllers must read the control tape piecemeal, while machining operations proceed. Historically softwired control had its origin in Direct Numerical Control (DNC) which utilizes one (large) digital computer to control a group of machine tools. Individual machine tool controllers which each contain a mini-computer or a microcomputer are known as CNC (Computer Numerical Control). They have been commercially available since about 1976 and have rapidly become the best selling type of NC Controllers in industry. Their operating software (Executive Programs) is still in the process of rapid evolution.

#### 2. Part Programming Languages.

The control information for a machining job is usually supplied to the controller on paper tape. Basically, there are three methods for the

generation of control tape as indicated in Figure B-1. Of these, the use of a parts programming language is the most prevalent and will be the only approach to be discussed below.

Part programming languages are systems of symbols (letters, numbers and special characters) which can describe machining operations. About 50 such languages are presently used in the U.S. Many of these are good for only one machine tool model. Those will not be considered here--only the most popular "higher level" (i.e., machine tool independent) languages will be dealt with. Initially, the APT (Automatically Programmable Tool) language will be described. Compact II and derivatives of APT will be contrasted to it later on.

a. APT. The Automatically Programmable Tool language requires the use of two software modules in succession, when a control tape is to be produced from a source program (see Figure B-2).

The processor handles those computations, which do not depend on the machine tool to be used. It is a large computer program, which is usually written in Fortran and consists of on the order of 30,000 Fortran statements. Many hundreds of manyears have been invested in the writing of APT processors. During the execution of the processor, large tables have to be set up in the working memory of the computer. The full APT program, capable of processing for 5 axis machines requires, therefore, a large computer. In the early 1960's, when APT came into industrial use, an IBM 360/65 with 256 Kbytes of core was a typical machine for it. That was then a large and expensive computer.

The APT language is in the public domain and is the topic of an ANSI standard. Many APT processors for specific computers, however, are proprietary.

The post processor implements the computer work that depends on the machine tool and its control unit. Post processor programs range in size from about 1000 Fortran statements for a simple positioning system to 5000 Fortran statements for a complex contouring machine. The writing of a post processor will consume between 0.5 and 4 manyears. A Post Processor must match characteristics of the machine tool and features of the control unit. Corresponding to the large number of machine tool/controller combinations in use today, there exists an equally large number of post processors. Post processors are usually proprietary. Some software vendors (e.g., United Computing Corporation, University Computing) claim to have over 1000 post processors in their Software Libraries. Nonetheless, one has to check on the availability and cost of the post processor whenever new tools/machine controllers are to be purchased. The total programming effort invested in post processors exceeds that of the main processors. The economic incentive to reduce

the cost associated with post processors through some form of standardization is strong, but to date, little has been accomplished in this respect.

A listing of some major computational tasks accomplished by the processor and post processor respectively is given in Figure B-3.

Figure B-4 provides an overview of the kinds of programming statements used in the APT language. APT programs consisting of such statements are punched on cards for input to a computer. Based on the source program, the processor produces a cutter location file (CL file) which is usually recorded on tape or disk. Many of the records in this file are the coordinates of points through which the cutting tool must travel (hence the name CL file). However, a variety of other information must also be communicated to the post processor and/or the machine control unit. To this end, APT provides a classification scheme for the logical records of the CL file (see Figure B-5). The CL logical record classification of APT has been adopted by many parts programming languages with little modification and the International Standards Association has adopted a standard based on it (ISO/DIS 3592). This makes the cutter location file an attractive candidate for exchange of NC machining data between different installations. It should be noted, however, that tape exchange requires standardization beyond the logical format. The physical characteristics (diameter, etc.) of the tapes and the tape coding/decoding process must also be standardized.

It deserves to be noted that the toolpath described in the CL file delineates the travel path for the center of the tool and not a path on the surface of the part. The path in the CL file is displaced from the path of the cutting process by the tool diameter. Thus, the work of the processor, which is supposed to be independent of the machine that will be used, is not independent of the cutting tool. This convention for the CL-data was necessary in the early days of NC, when it was not possible to provide adjustment for the cutter diameter in the controller. It is rather inconvenient for interchange of CL files and for the reuse of old control tapes.

In spite of these obstacles, the CL file appears to be a better candidate for NC data interchange than either the source program written in a high level parts programming language or the machine control tape. The reasons for this conclusion will be presented later.

The tapes (paper) used for input to commercially available machine tools are generally in conformance with the standards of the Electronics Industries Association (see Figure B-6). The tape has eight tracks (columns) and accommodates 10 characters/inch as specified in RS-227. The 8 bit characters, which are punched one per row, either use the old "EIA code" (RS-244) or the ASCII subset which has become EIA standard RS358.

This is a subset of the 7 bit plus parity code, which provides for up to 128 possible characters. On the basis of comparison to the EIA code only 52 characters are included in the RS-358 standard; considerable expansion into the use of other ASCII characters is possible. The EIA code originated from a 6 bit code, which can maximally offer 64 character encodings and has little room left for expansion. EIA no longer supports RS-244. The ability to accept ASCII code should be mandatory for all new machines.

Tape formats describe how sequences of characters will be organized into words and blocks of information. Roughly, a word is a unit of information destined to replace the content of one register in the control unit. A block is a set of words, which prepares the control unit for the next machining operation. Tape formats (variable block length or fixed block length) are presently covered by RS-274C. This standard, which was adopted in 1974, has superseded both the older standard RS-274B for variable block length formats (word address format and tab sequential format) and also the fixed block length standard RS-326A.

The standard RS-274C has been formulated with a control unit in mind that reads words from the tape into the registers of the control unit for execution. It does not consider that the whole tape might be loaded into the memory of a CNC controller and that some data processing of the information could be performed there. The standard RS-274C outlines requirements for exchangeability of control tapes between machine tools. In some respects, the conditions stated there are more restrictive than they have to be for CNC machines.

The preparation of a control tape for a part by the post processor program takes many characteristics of the machine tool into account. For instance: machine tool dynamics, corner overshoot, geometry of the machine, location of holding devices etc. A control tape cannot be exchanged between two machines even if both can produce the part and use the same tape format if there exist differences in these physical characteristics.

The history of APT is summarized in Figure B-7. The appearance of an APT standard prepared by the American National Standards Institute (ANSI X 3.37) at the bottom of this table might seem to indicate that the language has been standardized to the point where APT source programs are portable (exchangeable). Unfortunately, this is not the case. Post processor language was not part of the (first) 1974 version of the standard. In 1977, some language regarding post processors was added to the standard. It is, however, not strict enough to assure portability. A commendable effort toward post processor standardization is in progress at NBS, but its success is not assured yet. Further, the existence of the standard does not mean that the language is by now so mature and so complete that updating is no longer warranted. Indications were found

that the custom of periodic updates by one organization (like ITTRI or CAM-I) has ceased and that instead some commercial users are now advancing proprietary versions of APT on their own.

b. Compact II. The Compact language is designed for use on remote terminals of a time share system. For simple parts and 2 axis machines (lathes) the programming effort in Compact is smaller than in APT.

The principal difference between processing of a parts program in a batch processing language and in a timeshare language are illustrated in Figure B-8. In the batch mode there will be several successive passes which each handle certain aspects of the conversion. In each pass the work on all statements (the entire program) is completed before the next pass is begun. In a timeshared operation the processing of each job is broken down into small time intervals, which are separated by the intervals allocated to other programs, and the amount of working memory for a program has to be kept small. The design of a language for timesharing must, therefore, provide that a small portion of the source program (an individual statement) will be processed completely before the processor turns to the next segment of the source. The language must consist of statements, which are less dependent on each other than the statements of a batch processing language.

The completion of all the computer work on a statement by statement basis circumvents the need for a CL-file and the Compact language was originally designed not to have one. With an eye toward exchangeability, the creation of a CL-file has been added to some Compact processors. Presently, at least one vendor (University Computing) can produce CL-files which fully comply with the APT format.

Editing, program modification and the interactive use of graphics terminals are facilitated by the high degree of independence between Compact statements.

The output of error messages in response to a faulty input statement in Compact is immediate. The contrast of Compact II and APT among the parts programming languages is in many ways comparable to that of Basic and Fortran in the area of general programming languages.

Compact II is a creation of MDSI (Management Data Systems, Inc., Ann Arbor, Mich). It is a descendant of the languages Split (Sundstrand Corp.) and Action. Standardization of Compact by ANSI has been initiated. Some additional comparisons of Compact and APT are included in Figure B-9.

c. Derivatives of APT. The bulk of the parts produced by NC machining does not utilize the 4 or 5 axis capability of APT. The desire to simplify programming for these applications and to make do with a

small computer has spawned the development of several APT based languages (see Figure B-9). In contrast to the original APT, the processors for these languages have a modular structure.

ADAPT (Adaption of APT) was developed with sponsorship of the Air Force and General Electric for use on small computers and in timeshare systems. Processing on (at least some machines like IBM 1620) is disproportionately slow in comparison to regular APT.

UNIAPT (United's APT) was developed by United Computing Co., (Carson, Calif.) for use on PDP computers (and similar machines). It offers the full power of APT, from which it differs mainly in the internal workings of its processor. United offers a graphics system which can be connected to the UNIAPT computer for display of the C-L path. It is possible to input parts into such a system graphically. United Computing Co claims that the "source code generator" of this system can produce APT source documents for parts which have been inputted through the graphics system.

EXAPT (Extended APT) makes machinability calculations (e.g. selection of feedrates and cutters) the computer's responsibility. To this end, a "technological processor" is placed between processor and postprocessor (as shown in Figure B-2). This development is, in some respects, a competitor to the use of adaptive control.

Two versions of APT which have been introduced quite recently are Miniapt (University Computing) and Microapt (LeBlond). Miniapt is a three-axis version of APT that requires 64 KBytes of storage. Microapt attempts to utilize the low cost of a micro-processor based computer-system vis-a-vis the continuing costs of timeshare communications to recover for APT some of the NC market that it has lost to Compact in recent years.

A variety of company implementations of APT add special purpose modules to the language (examples: turning modules like IFAPT (Adera, France)), sculptured surface modules (e.g., Boeing's BSURF) or permit the addition of routines written in a general language like Fortran to the parts processing software (e.g., MACAPT of McDonnell-Douglas Automation Co.).

One company has written a "pre-processor" program for APT and claims that this will reduce programming time and time spent by the APT processors for debugging purposes.

### 3. Softwired Controllers (CNC).

Softwired controllers contain a microprocessor (or minicomputer) with memory in the control unit. The controller logic, which in previous controller technologies was implemented in hardware, is programmed into

the executive program, that is stored in a memory. Memory is also used to store the information from the control tapes.

The features and options provided in a softwired controller are accomplished through the software; the controller hardware is, therefore, more standardized and the number of hardware components is much smaller than in hardwired controllers. Adding-on of features will require re-programming of the executive program, which is much less costly than the corresponding addition of hardware in the older controller technologies. The limiting factors for the expansion of the executive are mainly the memory size and the physical limitations of the machine tool. The computing speed of the microprocessor will usually be more than adequate. Some examples of uses of the flexibility of programmed executives in present-day controllers are: Acceptance of both ASCII and EIA code characters, of several tape formats, of English and Metric Units, of absolute and incremental coordinates and the implementation of offset compensation for the tool diameter.

The computational capabilities of the CNC controller make it possible to shift some of the work that was previously done in the processor or post processor into the control unit. Examples: The sophistication and diversity of canned cycles which are implemented in the controller is increasing rapidly and more interpolation routines (e.g. cubic) are being offered. This leads to shorter control tapes for the same job. Manual programming becomes feasible for some jobs, which previously were too laborious for this. At times, in manual programming of CNC machines advantageous moves can be made, which are not possible when a parts programming language is used. Many vendors offer the capability to edit (modify) control tapes in the controller and some offer CRT terminals (e.g. for display of the CL path) for assistance in this task. Floppy disks may then be employed to provide sufficient memory. Manual programming, editing and proofing of control tapes on the shopfloor allow for very quick reaction to new requirements, but this also has the potential for great damage and injuries. It is highly advisable to limit the access to these features to competent and authorized personnel by means of a software key (password).

Present day executive programs have a modular structure which facilitates changes. Changes are usually implemented by the controller manufacturer, who supplies the executive program with the equipment and not by the machine tool owner. Often, the executive will be stored in non-volatile read-only memory (ROM or PROM). Operating programs stored in such a medium are known as firmware.

The control information for a part is stored in read/write memory. Typically 100 to 200 feet of control tape (12,000-24,000 8-bit characters) can be stored. This is usually sufficient for at least one entire part. The part program will be loaded into the memory once and



then used repeatedly until the batch of items is manufactured. In earlier controller types, the control tape had to be read one block at a time during the machining of a part. The tape had to be run through the reader once for each part and reading and machining had to be well coordinated timewise. The wear of the reader and the tapes was much higher.

Some CNC executives provide for a foreground/background mode of operation. In this case, one can load/edit/debug a new tape during machining with the previous one. The limiting factor for the potential capabilities of most controller types is the size of its memories. Expandability of memory is very important for adaptability to future needs.

CNC is the most recent controller technology (see Figure B-10). The EIA standards and the military specifications dealing with numerically controlled tools were formulated before CNC became prevalent. The standards are, therefore, often inadequate for CNC. Parts programming languages and post processors are the only software mentioned in the Mil-specs in connection with controllers; CNC executive programs are never mentioned and many of their capabilities are described as hardware features.

Some CNC control units can be programmed to collect use data (machine uptime, etc) for the machine tool. This is useful for cost and utilization studies. Alternatives to paper tape (diskette, solid state memory, cassette) for the machine control program are being offered by some vendors, but are not widely used yet. In DNC (Direct Numerical Control) the control information is transmitted electronically from the host computer to a number of machine tools. This approach is not quite as attractive today as it was prior to the advent to CNC, nonetheless, electronic data transmission to CNC controllers ("going in behind the tapereader") is being used in practice. The ICAM report (Air Force) states that this ought to be preferred over punched paper tape.

Many people in the field expect that the shift of computer processing into the control unit will continue. There exists to date at least one control unit, which contains the post processor program and receives the CL-file as controller input. The prediction, that at some future date, even the main processor will be stored in the controller so that APT source programs can be inputted directly into the controller, has been made in the 1978 CAD/CAM Handbook.

#### 4. Intelligent Terminals.

Terminals are said to be "intelligent" if they are programmable, i.e. software or firmware controlled. They have come into use in the early 1970's as remote input/output devices for digital computers. In the NC

field, CRT terminals are used in interactive graphics systems and as monitoring devices for CNC controllers. Microprocessors are frequently found in terminals. Their impact on terminal devices has been similar to that on control units.

The CRT terminals used in interactive design must have a line drawing capability: After the endpoints or other characteristics of a line or curve have been inputted, the desired line segment has to be automatically generated under software control. Direct high speed communication between the computer and the display element is necessary to accomplish this. CRT displays other than storage tubes, need to be refreshed periodically (typical refresh frequencies are 50--60 Hz). A memory of 250000 to 400000 bits per image is necessary. Of the various memory technologies that can be used for this task, the magnetic disk is probably still the least expensive at present. Magnetic bubble memories might replace it in the future. Two techniques for refreshing are in use: Raster Scan and Random Scan. Raster scanning directs the electron beam periodically across the entire screen and varies the beam intensity to create the images. It is the technique used in commercial TV receivers. The quality of the images obtained by Raster Scan is inferior to that possible with Random Scan and is insufficient for many engineering tasks. However, Random Scan is also more expensive. In the Random Scan method, the path of the beam is controlled to trace the desired shape.

The inputs to a graphics terminal are supplied via keyboard and lightpen (in case of Raster Scan) or cursor (a marker that can be positioned from the keyboard or by means of a joy stick).

Interactive design on a graphics terminal is performed using a design language to create the desired geometry on the screen and in a data base of the system. The language will also provide that supplementary information (tools, feeds, etc) can be entered into the data base. The design language of the graphics system is in many ways the equivalent of a parts programming language for the graphics terminal, but requires considerably less effort of its user. There is so far no design language for use on terminals, which comes close to being a standard-like APT or Compact II for traditional computer assisted parts programming. Every terminal manufacturer offers a language specifically for his equipment. Examples: Fastdraw (McAuto), Idraw (IDI), DAL (Design Analysis Language of CALM), TIGS (Terminal Independent Graphics System of Control Data), Unigraphics (United Computing).

Design languages typically contain a set of primitives, which can be called from a memory and positioned on the screen in any desired position. From the draftsman's viewpoint, the primitives are the equivalent of the shapes available on templates in manual drafting. The machinist may liken them to the canned cycles in a CNC controller. Some design languages let the user create his own set of primitives.

The software used in graphics terminals is usually purchased with the hardware from the manufacturer and is proprietary. Frequently, this software seems to be written in Fortran, sometimes with subroutines in an assembler language.

Interactive design offers more than a swift way to enter a parts description into a digital data base. Tentative designs can be subjected to a variety of analytical tests in the system. Several companies offer a library of analysis programs (e.g., finite element analysis for mechanical designs) for use in their graphics system. Users, who wish to use the terminal primarily as an input device for previously confirmed designs, will not need this kind of software. Input via terminal circumvents the use of a parts programming source language. The parts description that is produced in the data base will resemble the CL-file of APT. In at least one existing system (Unigraphics), the graphics output is exactly in the APT CL-format, so that the same post processors can be used.

Another way to bypass parts programming is the use of a digitizer. A scaled (and often considerably enlarged) drawing is inspected by an optical scanner which produces digital output for the data base. Once again, a computer and a (more restricted) user language will be part of the system.

#### 5. Recommendations.

a. It shall be permissible to deviate from existing military specifications and applicable commercial standards whenever this is necessary to permit the use of softwired control in lieu of hardwired control.

Comment: Even the most recent Milspecs and EIA standards have been developed before the advent of control units, which contain a micro-processor and executive software.

b. All software acquired in connection with NC or CAD-CAM systems shall possess a modular structure (unless it consists less than 256 Bytes). Each module shall be documented individually.

c. Memory expansion capability shall be called for in softwired control devices.

d. Softwired devices shall be protected against unauthorized and incompetent use by software keys (passwords, that are programmed into the operating software).

e. New controllers for NC machinery shall be softwired.

f. New controllers for NC machines shall, as a minimum, provide the following features:

- (1) ASCII (RS 358) Code for input
- (2) Absolute and incremental position input
- (3) Input in both British and Metric Units

g. Controllers, which can be equipped with a hardcopy output device (paper tape punch, disk, cassette, etc.), shall collect use information for the NC machine (Machine uptime, execution time for jobs, etc.) through a routine in the controller software.

Comment: The intent of this requirement is to assist in the data collection for the economic post analysis of NC machine use (as required in AR 5-4, DA PAM 700-23, Form DD 1651) and called for in reviews by the GAO. (e.g., Report: "Followup Assessment of the Use of NC Equipment to Improve Defense Plant Productivity.")

h. The use of electronic transmission of control tape information from a computer to the machine control units shall be encouraged. The electronic input shall interface "behind the tapereader". The machine control unit of such systems must run independent of the host computer during job execution and shall be equipped for hardcopy input on the shopfloor as an alternative.

Comment: This is recommended in view of the goal of "Routine Electronic Data Transmission for Numerically Controlled Industrial Plant Equipment Between Facilities by 1985" (quoted from a draft A.R.), and to provide compatibility with the recommendations of the ICAM study of the Air Force.

i. The logical format of APT for the CL-file shall be made a required standard. Use of parts programming languages, other than APT (e.g. Compact II), may be permitted if they produce an APT compatible CL-file.

j. A standard for magnetic tapes, that will serve as medium of storage and exchange of CL-files, shall be developed.

k. The use of standardized post processor commands shall be considered for new equipment once they become available.

Comment: The development of standardized post processor commands is in progress at N.B.S.

l. Interactive graphics systems shall permit the user to program his own set of primitives into the system.

**PREPARATION of CONTROL TAPE:**

**a) MANUAL**

**b) PARTS PROGRAMMING  
LANGUAGE**

**c) COMPUTER GRAPHICS**

**FIG. B-1**

# APT COMPUTER PROCESSING

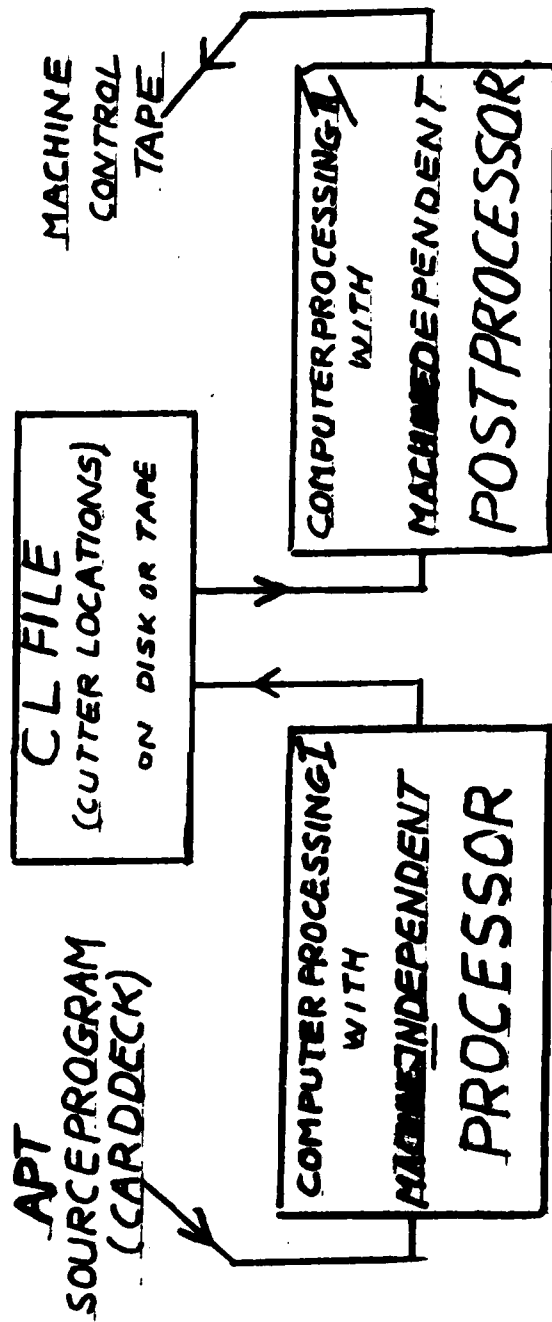


FIG. B-2

# SOME MAJOR TASKS OF

## PROCESSOR

1. COMPUTE CUTTER LOCATION POINTS FROM GEOMETRY & MOTION STATE -  
RESULTS: ENTER INTO CL FILE
2. CONVERT POST/PROCESSOR STATE -  
RESULTS INTO CL RECORDS
3. PRODUCE PARTS PROGRAM LISTING
4. " " CL FILE
5. " " ERROR MESSAGES

## POST/PROCESSOR

1. READ CL FILE
2. CONVERT TO MACHINE TOOL COORDINATES
3. CONVERT TO ABSOLUTE/INCREMENTAL
4. CHECK FOR MACHINE TOOL LIMITATIONS
5. DEVELOP FEED RATES/SPINDLE SPEEDS
6. " MOTION COMMANDS WITH CONSIDERATION OF MACHINE DYNAMICS (SAFE ACCELERATION/DECELERATION, CORNER OVERSHOOT)
7. PREPARE USE OF INTERPOLATION
8. PUNCH CONTROL TAPE
9. PRINT OUTPUT LISTING
10. PRODUCE ERROR MESSAGES

FIG. B-3

# TYPES OF APT STATEMENTS

TYPE	USE	EXAMPLES
AUXILIARY	guide processor	CLPRNT
	execution	CUTTER/.25
	guide	PARTNO
POSTPROCESSOR	guide	COPLNT/ON
	postprocessor	FEEDRAT/5, 100
	execution	TURRET/3
GEOMETRY	describe	P1 = POINT/-1, 1, 0
	shape	L2 = LINE/P1, P2
	of part to be made	C3 = CIRCLE/1.5, 1, 0, 0.5
MOTION	direct	G0 T0/P1
	motion	G0 D1TA/2, 1, 1.5
	of cutter	G0 LFT/DSURF, PAST, ASURF

FIG. B-4



# CUTTER LOCATION FILE (CL DATA)



## APT 3 LOGICAL RECORD CLASSIFICATION

50101	CODE	
1000	APT STATEMENT NUMBER	
2000	POST PROCESSOR COMMAND	
3000	CANONICAL FORM GEOMETRY (CIRCLES)	
5000	CUTTER LOCATION	
6000	POST PROCESSOR FLAGS (TOLERANCES)	
9000	AXIS MODE	
13000	INTERNAL ERROR FLAGS	
14000	FILE CODE	
23000	USER PROPRIETARY RECORDS	
32000		

FIG. B-5



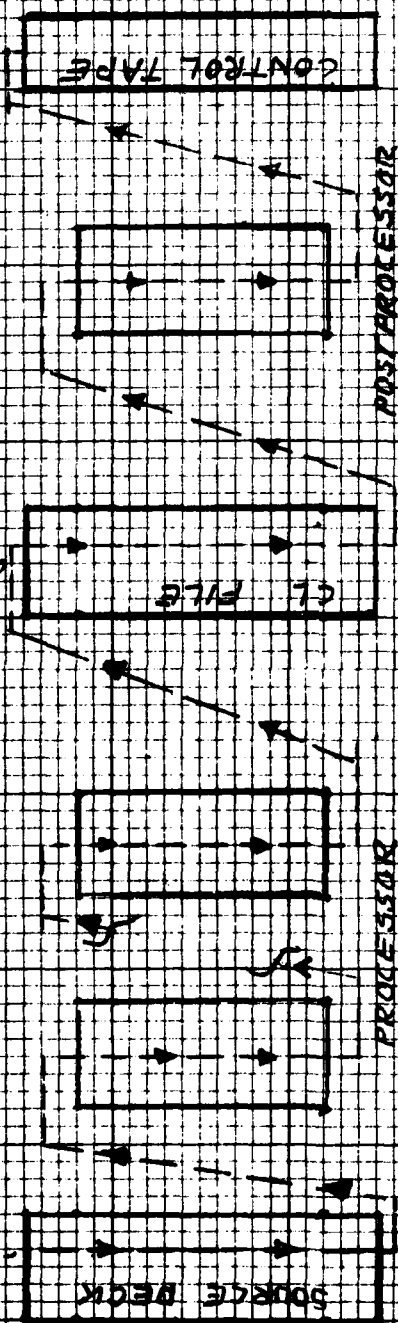
# HISTORICAL SKETCH OF APT

1952	FEASIBILITY OF N.C. DEMONSTRATED AT <b>MIT</b>	1971	APT 4 INTRODUCED. <b>CAM-I</b> (COMPUTER AIDED MANUFACTURING-INTERNATIONAL), A NONPROFIT ASSOCIATION OF INDUSTRIAL ORGANISATIONS, ASSUMES RESPONSIBILITY FOR MAINTENANCE ITS WORK IS SUPPORTED BY MEMBERSHIP FEES. RESULTS ARE (USUALLY) RELEASED INTO THE PUBLIC DOMAIN ABOUT TWO YEARS AFTER THEIR PUBLICATION FOR MEMBERS.
1955 ↑ ↓ 60	DEVELOPMENT OF APT AT MIT, SPONSORS: AIR FORCE AEROSPACE INDUSTRIES ASS	1974	ANSI STANDARD FOR APT (X3.37)
1961	APT 3 RELEASED FOR PUBLIC INDUSTRIAL USE. ILLINOIS INSTITUTE OF TECHNOLOGY RESEARCH INSTITUTE ( <b>IITRI</b> ) CHARGED WITH MAINTENANCE (QUARTERLY UPDATES)		

FIG. B-7

# PRINCIPAL PROCESSOR OPERATION

## a) BATCH PROCESSING MODE (APT):



## b) INTERACTIVE (TIME-SHARE) MODE (COMPACT):

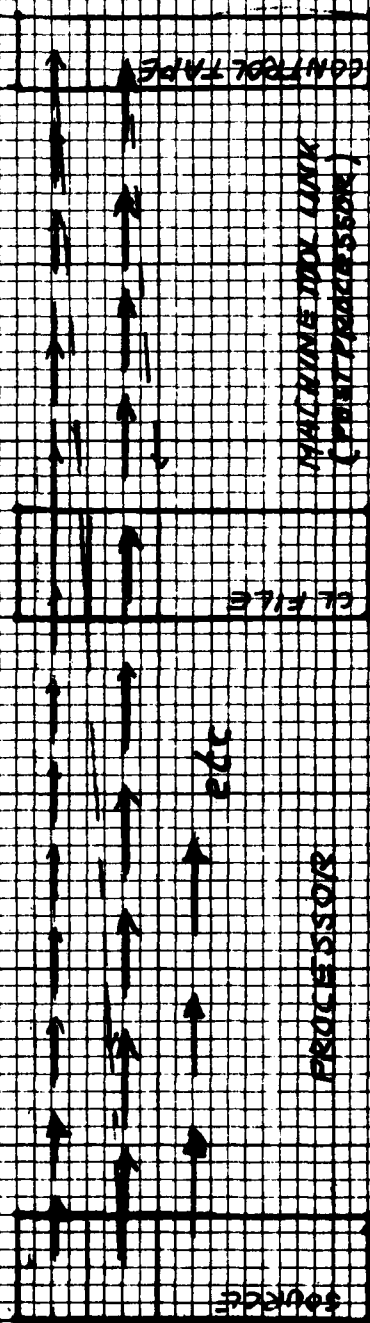


FIG 15-8

# SOME LANGUAGE COMPARISONS

1977 STATUS

a) NOT APT BASED:

NAME	INTRODUCED	PROPOSED	MAIN	MOTIVATION FOR INTRODUCTION	COMMENTS	EXTENDED USE	LANGUAGE
COMPACT II	1969	MOSE		USE TIME SHARED (INTERACTIVE) COMPUTER	EFFICIENT FOR SIMPLE PARTS	29% RARELY	YES

b) APT BASED:

NAME	INTRODUCED	PROPOSED	MAIN	MOTIVATION FOR INTRODUCTION	COMMENTS	EXTENDED USE	LANGUAGE
ADAPT	1960	ELTRI	CLAM-I A.F.	FIRST GENERAL PARTS PROGRAM LANG. REQUIRED APT FOR SMALLER COMPUTER	LARGE COMPUTER MOSTLY PUBLIC SLOW ON SMALLER COMPUTER	39% 10% 3%	SOME
UNIAPT	1969	UNITED COMPUTING CORP.	G.E. A.F.	FULL APT CAPABILITY FOR MINICOMPUTER	GOOD YES INTO COMPUTER GRAPHICS (100K)	3% YES	YES
EXAPT	1965	FRANKLIN UNIVERSITY'S	GERMAN	INTELLIGENT MACHINE LEARNING CHALLENGES IN PROCESSOR	SOME MACHINE LEARNING IN PROCESSOR	3% YES (10%)	YES

FILE # 81

# HISTORICAL SKETCH OF CONTROLLER TECHNOLOGIES

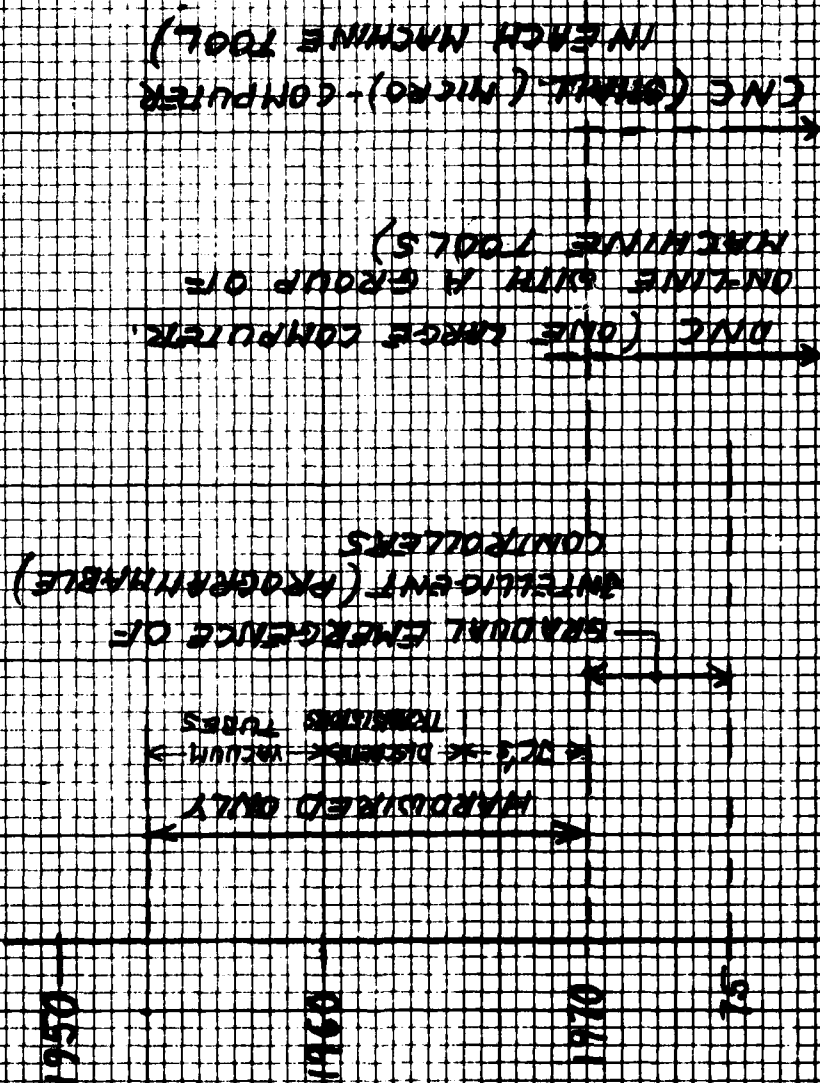


FIG. B-10

Appendix C  
INTELLIGENT HARDWARE

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11. FIGURE C-7: NC machine tool system.
12. FIGURE C-8: Comparison of Systems I, II, and III.
13. FIGURE C-9: A CNC lathe with "show-and-tell" graphic display, automatic self-programming system, built-in postprocessor and tapeless spindle control.



## INTELLIGENT HARDWARE

### 1. INTRODUCTION.

A definition of "Intelligent Hardware," as it applies to Numerical Control (NC) Machine Tools, needs to be presented before the purpose of this phase of the study can be meaningfully covered. As would be expected in this age of computers, it follows that intelligent hardware means that the NC machine has some type of computer directing the programming and machine control functions and is capable of interacting in an intelligent manner with the parts programmer and operator.

Intelligent hardware is presently found to constitute a major part of a NC machine tool complex such as found largely in industry and to a much lesser degree in the Services. Such hardware includes mostly computers, terminals, controllers, interactive graphics (CRT, displays, monitors, etc.), and plotters. Most of these units interact with the user to provide a so-called intelligent feature to the system. The advantages of such a system are many and are considered in detail later. As an example, such hardware results in a major savings in time and costs, in parts design, and programming. Even more importantly, much less training of the users is required. As an important consequence of these significant advantages, the development and production of the new and more sophisticated intelligent hardware are advancing at such a rapid rate that the user -- industry and government -- are hard pressed to keep pace with the myriad of new improvements let alone take advantage of them for their facilities.

With this introduction of intelligent hardware, the purpose of this section clearly becomes that of presenting first pertinent and factual data about such hardware currently being used successfully and in operational state. Secondly, some facts about what the future will have to offer in intelligent hardware are of vital concern. For example, the purchase of NC equipment planned for the Army Depots for, say, 1980 and on, should take advantage of the state-of-the-art NC intelligent hardware to be available at that time; therefore, another purpose of this study is a prediction, based upon some standard inputs, on the kinds of equipment to be expected in the near future.

A final purpose that follows from the analyses of the facts collected, is the recommendation to the various depots of the kinds of NC machine tools to acquire along with a set of regulations for their purchase and use.

Included in the general topic of intelligent hardware are a number of major sub-topics that require separate and collective treatment. These are as follows: (1) Computers (large main frame units, minicomputers and their included micro-processors), (2) controllers of the machine

tools, (3) interactive graphics, (4) adaptive control of the machine tool, and (5) the training of personnel involved in their use.

Because of the close interrelationship of intelligent hardware and the software, the subtopic areas of another part of the study dealing with NC software, parts programming languages, postprocessors and the interchange of software data are necessarily included wherever required in the analyses.

## 2. FACTS.

A number of facts of major importance, and also some of lesser significance were established by collecting a wide range of data on intelligent hardware by a program of visitation by the DESCOM NC/CAM Study Group to Army, Navy, and Air Force depots having operational NC machine facilities. Complete NC intelligent hardware along with the necessary peripheral equipments (teletypewriters, printers, card readers, etc.) were observed in operation; furthermore, actual parts programming and machining were demonstrated. Information in each case was collected, analyzed, and cataloged on computer and peripheral equipments, operational procedures, parts programming, paper tape production for running the machine tool, and the actual milling and drilling of sample parts.

A wealth of factual data were acquired also from industry. A different set of procedures was followed to ferret out useful information on prevailing hardware and new developments. Brochures and reports were ordered, discussions were conducted with company technical representatives, and equipment exhibits and demonstrations were attended. To complete the fact finding exercise, NC machine tool shows, conferences and workshops were attended. All of these data were used to provide a basis for specifying not only intelligent hardware but total guidelines for the purchase and operation of NC machines by the Army Depots.

An important observation by the visitation teams was that a number of the Tri-Services depots visited already have successful NC machine tool facilities. They have established guidelines and regulations necessary for their operation. These facilities served as models for the study and influenced the results of the same. Although much of the information received was quantitative in nature some of it was qualitative and had to be weighted accordingly.

One fact is clear, the study showed there to be a marked difference of opinion of the kinds of NC machines and accompanying intelligent hardware that should be used by the military and industry. However, from this rather extensive study, it appears as though the bulk of parts manufactured by the Services using NC machines require only a 2- and 2½-axis

machine capability. The machine operation requires milling in one plane with simultaneous tool movement in both the X and Y directions, and an independent setting of the tool perpendicular to the plane (2 direction). Roughly, 50 to 80 percent of the machining fits this category. Only a few of these parts are generally simple enough to be parts programmed manually using the oldest and most widely used EIA (Electronic Industries Association) code to produce a machine-tool control tape. Conversely, with large companies such as found in the manufacture of aircraft, cars, etc, NC machines are set up to produce thousands of the same kinds of parts with machining ranging from very elementary to highly complex milling, drilling, and tapping operations. Consequently a 5-axis NC machine (three linear and two rotational axes) is a "must" and is dedicated to the manufacture of complex parts as well as simpler parts to insure maximum utilization of the machine, and is easily justified economically.

The visits to the numerous depots showed unequivocally that their respective missions for DESCOM varied considerably and that their needs for NC machines differed appreciably. The information gleaned from these observations pointed early towards the need for categorizing a number of representative NC systems that could be recommended for a particular depot or a concerted group of depots. Again, based upon the information and facts collected by the visitations, company brochures etc., NC systems that are now in an ongoing status, or found to be fairly well defined, fall into one of the three general categories listed below. The intelligent hardware of each of these systems is presented in concept and discussed later in detail.

a. System I. This arrangement of hardware designated as System I provides a computer service to a number of depots which are located in the same geographical area that usually covers a number of adjoining states. A large computer such as the IBM 360-65, which has the capacity of 262 Kilobits/min. to 1048 KB max. is located centrally in this area and provides a very rapid high capacity computing capability to the subscriber depots. All of the computations are done on a time-sharing basis so as to provide -- in an average time of roughly 30 minutes -- the calculations necessary to punch a paper or mylar tape in EIA or ASCII code that is used to run an NC machine. The system is capable of computing tapes for a large number of NC machine tools by selecting the proper postprocessor program stored in the large memory of the main frame computer. Each NC machine type of a different manufacturer requires its own computer postprocessor program. The final processed data are then transmitted back to the originating depot where they are stored in a local memory bank or used immediately to punch a machine control paper or mylar tape in EIA or ASCII code. The tape is delivered to the shop and mounted in the NC machine controller for making the part.

In summary, System I provides a large noninteracting central computer to perform the computations for the number of depots tied to the computer through dedicated telephone lines. All peripheral equipment and machine tools are located remotely at the depots. Programming language mainly is APT (Advanced Programmed Tool). The computer has the capacity to perform 5-axis tool path computations. Cost of a large computer requires a major investment around 2 million dollars; however, System I is a high performance system capable of handling the most complex machining task. Furthermore, the cost of leasing the dedicated telephone lines is a major operating expense.

Figure C-1 shows the elements of System I and some indication of the operations conducted at each remote depot as well as at the central computer complex. Complete details of this NC system are given later.

b. System II. The main differences between System II and System I are: (1) the availability of a large computer located at each depot rather than having a remote time-shared centrally located computer, plus (2) the addition of a number of Computer Numerical Control (CNC) machines to make up the total system. Here the large computer can be of the IBM 360-65 variety (Univac, Honeywell, etc.) or notably a relatively low-cost minicomputer such as a PDP-11, with a 16-bit capability and a 32 KB or more of disc memory. Such a system provides a depot with complete independence in parts programming of complex parts requiring 3 to 5-axis machining. It has also an added flexibility by having the CNC units available for simpler machining jobs of the 2-axis types. The companies manufacturing such equipments now offer a wide variety of CNC lathes and milling machines incorporating a large number of extra features. For example, a CNC machine with its included microprocessor can provide on site parts programming, editing features, interactive graphics showing cutter paths, inherent postprocessor, etc. Most of the CNC machine tools on the market today are of the "stand-alone" variety that are designed so that the part can be programmed, edited, and machined at the machine tool location (the shop area). The buyer of the CNC machine needs to decide which of these multitude of features are required for his shop.

In brief, System II is a total high-speed system with added flexibility over System I by the addition of CNC machine tools. The cost of the system is high but certainly meets the readiness criterion requested by the Army.

Figure C-2 shows the elements of System II for a depot installation. Complete details are given later:

c. System III. System III may be described as a "starter" system with provisions for expansion and add-on features without necessitating major disruptions to the system. A depot can start with the minimum of only one standalone CNC machine tool. A standard CNC input, which is

generally tied to a lathe or milling machine, usually provides a keyboard on the controller panel for manual parts programming, interactive graphics, editing at the machine, a postprocessor as an integral part of the total system, and operation of the machine from computer memory or from punched paper tape made at the local CNC unit or other separate parts programming systems such as Systems I and II.

CNC machines run the gamut from the most basic or stripped version to ones that are equipped to do the whole job from the design to the machining of the part. Such CNC units are capable of providing 2-axis simultaneous machining, and with some more elaborate designs extending to 3-axis and even more. CNC machines can be interfaced with mass data storage devices thus allowing the user to access a large parts programming library.

In summary, unless a depot already has a means of producing parts programs and punching a required EIA/ASCII machine controlled tape, a minimum requirement for establishing an NC machine tool capability would be the acquisition of very versatile CNC machine such as described above and shown in the block diagram of Fig. C-3. Such a system provides a building block for expanding to Systems I or II. Clearly, System III is a minimum cost installation, and readily expandable to a more capable system as the demand grows.

d. Interactive Systems. Another important fact that has evolved as a result of the rapid developments of NC machines deals with interactive graphics. One finds that any of the three basic systems outlined previously can be modernized by the addition of interactive graphics. The momentum towards replacing the drawing board and the time-consuming design methods is steadily increasing. Predictions indicate that interactive graphics will soon become an integral part of all CNC machine tools, or an integrated part of an NC machine tool system.

The components and features of interactive graphics are very close to, or the same as, those found in a Computer-Aided Design (CAD) facility. The part can be designed or copied from an existing drawing using a programming keyboard and cathode ray tube (CRT) monitor tied to an appropriate computer with associated software. From the instructions given to the computer, a part is either designed or copied and simultaneously a parts program (such as a parts manuscript) is placed into computer memory and then recalled to develop the cutter paths for the machine tool. Finally, with the designated postprocessor for the machine tool involved, the CNC mini-computer generates the commands required to operate the machine tool. These commands can be transferred to punched paper or mylar tape or memory where any of these sources can be used to operate the machine tool. The details of the investigations on the utility and applications of interactive graphics are extended in the following sections.

### 3. DISCUSSION.

When one faces a question on the kinds of NC machine tools to recommend for a depot, including the total support system such as intelligent hardware and software, the natural tendency is to look for a representative system that is enjoying successful operation in terms of supplying production demands and at the same time being cost effective. Such a representative system, designated as System I, shown in Fig. C-1, is found at McClellan Air Force Base, Sacramento, CA. This is a total and comprehensive system. Comparable systems, but structured differently, were visited at various Navy installations.

There were essentially no limitations found in the parts programming hardware or language of McClellan Air Force Base NC machine tool system. The only limitations came from the capabilities inherent in the individual NC machine tools found in their shop. Most of these NC machine tools were of the 2½ to 3-axis variety; however, NC machine tools with 5-axis control could easily be added any time to their operation. Such additions would only necessitate the inclusion of appropriate post-processors to the main computer.

After observing the operation of this system from input (parts programming) to output (milling of the part), there was a strong compulsion to recommend this system for the Army Depots. However, one must take into consideration the recent spectacular developments in minicomputers, microprocessors, and inter-active graphics, thus choices for recommending an NC machine tool system for the depots are increased as well as improved.

Turning away from such a system as observed at McClellan Air Force Base requires some strong justifications, because it is a total system and utilizes the Army's standard APT programming language and certainly meets the readiness requirement. To understand the reasoning behind the development and assembly of some of the NC machine tool systems requires looking back to the era around 1950 when such tools were being introduced for industrial use. This was the period coincident with the tremendous upsurge in applications of computers to industry and the government. Small computers of the minicomputer type were just in the stages of development.

Early, large computers, such as the series IBM 360, were essentially the only candidates for NC machine tool applications because of the limited features of all but the largest computers. Consequently these large multi-million dollar computers were selected to perform the computations of parts programs, especially those involving highly complex geometries. Shortly after the incorporation of large computers into NC tool systems the computer development picture changed remarkably. These changes opened up new choices for the installation of NC machine tools by

the user groups. Spectacular advances in the development of mini-computers and microprocessors were the reasons for these changes. Increased computational speeds of these small computers, larger memories and mainly the sizable reduction in computer costs have revolutionized the whole machine industry. These advance developments are manifested in CNC machine tools, and NC machine tools programmed and controlled by minicomputers. Add to these tools the current interactive graphic hardware and one has the main units being purchased by industry for modernizing their NC machine tool facilities. Thus, these contemporary advances in computer technology and production make it imperative to carefully assess the recent NC machine tools, which incorporate these computers, for their application to the Army Depots. Consequently, a comparison of the early large computer supported systems is made with the recent systems involving CNC machine tools, graphics and minicomputers so as to provide a basis for recommendation for the depots.

a. Comparisons. A first comparison is made of the parts programming features of the above-mentioned systems. The parts programming method, hardware, and language are key factors to consider and are of primary importance in the choice of a NC machine tool system. What are the ways open to program a part for a NC machine? The question is best answered by a knowledge of the kind of part to be machined, the material used, and the complexity of the part. Discussions with various people using NC machine tools show that most parts manufactured by the depots require simple milling and drilling operations of the 2-axis variety. Such parts programming can be done manually using the older standard EIA machine tape codes, but easily only for the simpler parts.

b. Direct Manual Programming. A simple part can be programmed as shown in Fig. C-4. Starting with the part print, a program manuscript is written using the EIA codes (transfers machine instructions, dimensions, etc.). These codes are punched into a paper tape with a Flexowriter - a punched-tape controlled typewriter usually having a standard keyboard. The tape is placed into the tape reader located in the NC machine tool controller, and it in turn automatically controls the operation of the machine tool. Three important facts are noted: (1) the parts programmer requires limited training needing only a good background in machining and some mathematics (algebra and plane geometry), (2) no computer is required to generate the NC machine tool operations due to the simple machining involved (primarily 2-axis), and (3) a minimal amount of processing hardware is required.

Direct manual programming varies with the kinds of hardware available. The new CNC machine tools provide an added capability by providing a keyboard for manual programming on the panel located at the machine tool. Since the CNC units usually include a minicomputer, more complex parts programming is also possible. For example, a preset sequence of events initiated by a single command, e.g. G84, programs a cycle/tab

operation. This quasi parts programming capability could be labeled as computer-aided manual programming.

c. Computer-Aided Programming. Even though the general run of parts programming require straightforward machine operations, some do require very complex tool movements, thus making direct manual programming impossible. Very large computers are enlisted to program these complex operations. The important scientific language of FORTRAN can be used to program the operation of the NC machine; however, it is involved and requires extensive training and programming skill. Consequently, special languages such as APT were developed to simplify the programming. The APT language grew up with the NC field and has over the years come to represent the optimum form of communication between the part programmer and the complete spectrum of NC machine tools. Englishlike words are used to describe a part and the machining operations. APT was developed for use on very large computers and turned out to be very beneficial. Because of the large capacity of these computers, the structure of the APT language was not limited by computer speed and storage restrictions. With a large computer such as the IBM 360/65, the most complex part can be programmed. This total capability is in accord with the Army's readiness requirement which states that depots should be capable of making any part required for maintenance, even of the 5-axis type.

APT, however, was not without problems. Because of the environmental conditions, costs, and operational complexities, large computers could not be brought directly into and under the control of the NC programming group. As a consequence, APT users had to resort to remote installations such as service bureaus, time share companies or separate in-house computer data processing facilities. This has resulted in slow turn-around times, increased costs for computer time and poor utilization of part programming NC machine tool resources.

The introduction of microcomputers offered a partial solution to this problem. With its low cost, limited installation requirements (no air conditioned facilities, etc) and ease of operation, these computers can be installed directly in the parts programming area (engineering department, shop or computer facility). At the beginning, one disadvantage of the minicomputer was that it could not handle all computations of the complex APT language. As a result, a proliferation of compromised languages--over 60--were developed to run on minicomputers (ADAPT, COMPACT, etc.); but unlike APT, none of them can handle the complete spectrum of NC machine tools from single point-to-point to continuous three-dimensional path applications.

Around 1969, minicomputers were developed which could perform 5-axis parts programming through the use of modified forms of the APT language, such as UNIAPT. Such minicomputer costs run around \$50,000 which is about 1/20th that of a large computer. These computers can be directly



operated by the parts programmer with turn-around times on the order of 5 to 10 minutes per run. Card decks containing the program manuscript data, ready to be loaded into much larger computers such as the IBM 360/65 or UNIVAC 1108, can now be processed on a small dedicated minicomputer. They have the popular feature of APT, such as nested definitions, implied check surfaces, subscribed variables, any orientation of tabulated cylinders, and multiple intersections.

To lend credence and momentum to the use of minicomputers, since they are found in CNC machine tools and graphic systems, it is important to discuss why they can perform essentially the same as the large computers. Most APT processors are designed to process part programs in 3 or 4 passes, plus a postprocessor pass. The first task does syntax checking, part program decoding and symbol and canonical form table set-up. The second task executes arithmetic statements and surface definitions. Then the NC and machine tool commands are generated. A fourth pass is used by some systems to perform a matrix transformation. The output of these three passes is a centerline file which acts as input to the postprocessor. A CLPRNT statement causes the input to the postprocessors to be printed out in the edit phase of the APT processor. In comparison, consider the UNIAPT language which is capable of 5-axis programming and can be done on a minicomputer. Although internally APT and UNIAPT are different, externally to the part programmer they are the same. The UNIAPT interval structure has been simplified into a two-pass process, plus postprocessing. The first pass of the UNIAPT is similar to APT; however, the second, third and fourth passes of APT have been combined into one pass by UNIAPT. This information shows that a minicomputer can be programmed in an APT-like language to provide 5-axis machine commands.

A mention was made of there being some 60 different parts programming languages. This raises three important questions: (1) why are there so many languages, (2) can they be programmed on minicomputers, (3) can they program complex parts? As expected since there were no regulations by industry or government on parts programming, the manufacturer simplified their NC machine tool product line by writing special programming languages to fit only their machine tool operations. With the aid of microprocessors and specially designed computer logic, the input program instructions are transformed directly to the machine tool commands. Most of these languages are APT-like in structure. A new development has even gone so far as to work with operator spoken instructions rather than typed instructions. These different languages are described in the 1978 Modern Machine Shop NC CAM Guidebook published by Gardner Publications Inc., Cincinnati, Ohio 45202. Nearly all of these languages have a limited vocabulary and are easy to program since they require minimal training of an operator or parts programmer. The importance of this comment is that a selection of the machine tool of the NC or CNC type with its own languages or procedures certainly complicates the

possibility of standardization. Would a depot want to purchase a number of lathes and milling machines, each having a different programming language? Finally, 5-axis programming is possible only with a few languages.

d. Compromises. As a second comparison, parts programming can be accomplished by an entirely different method by utilizing an interactive graphics set of hardware. The difference between interactive graphics and Computer-Aided-Design (CAD) systems is difficult to separate. Why? First, interactive graphics is a main component of CAD. Second, the most recent CNC machine tools, as indicated before, are including CAD features. The CAD system provides a direct part design capability thus bypassing the need for a drawing department and draftsmen. Similarly a CAD system interacts with the designer to develop a cutter-path program on the basic design data which was previously stored in a minicomputer. The designer of the CAD system usually incorporates some modified form of APT for the cutter path language. Included in the minicomputer storage are the postprocessors for the NC machine tools located in the shop. To generate the EIA tape commands, a key is depressed on the graphics control board and the minicomputer goes into action with the postprocessor program to execute the data for punching the NC machine tool tape. A comparison of System I APT programming procedure with that of an interactive graphics terminal is given in Fig. C-5.

Note the operations deleted in the APT procedure by using the interactive graphics technique.

Interactive graphic systems are not new and have been operational for over 3 years. One such system operating successfully at the Corpus Christi Army Depot (CCAD) is shown in Fig. C-6. Of particular interest are the three graphics CRT terminals for the design of parts and the minicomputer that executes the commands for the operation of the paper tape punch. A small 8½ x 11 in. paper copy can be produced for reference purposes of the graphic displays. A separate CAD/CAM system is tied to the interactive graphics entity to produce large templates or standard-sized drawings. Plotters of all sorts and sizes are available to produce standard drawings.

Just from the comparison of the various parts programming methods and the systems in which they are used, it becomes noticeably clear that the choices for the selection of intelligent hardware are numerous. Before drawing any conclusions from the data, the individual components, e.g., computers, controllers and adaptive control of a total NC system need to be discussed along with the training required for their operation and maintenance.

e. Computer Systems. In selection of NC machine tools for a depot, one is concerned with computer systems which include numerous peripheral devices such as videotape archival systems, card punches, paper tape

readers, and user terminals (teletype and monitors). From the studies, there are two very well defined computer systems used for NC machine tools, mainly, large and small scale, or minicomputer, systems.

A number of depots and manufacturing companies with large NC machine tool operations use a large computer system. The computer system however is time-shared with the inventory, payroll, research, test, and other departments. Questions may be raised as to what are the arguments for the installation of large computer systems? These are: (1) the capability of performing the computations in APT for any complex part, (2) high speeds, (3) large storage capacity and (4) the ability to do large-scale tasks, such as operate a Direct Numerical Control (DNC) installation.

As a point of information, some characteristics of a large scale computer system are reviewed. A large-scale system is one based on a main frame in the range of IBM's System 370, Model 159 through Model 3033 (older model was the IBM 360). These are usually computers with processor speeds ranging from 30 to 150 nanoseconds (billionth of a second). They are capable of executing several million instructions per second.

The profile of typical large system applications is undergoing a number of changes, reflecting the growing shift towards networks of smaller dedicated systems.

Applications suited to large systems include nearly every type of processing: remote batch, time sharing, transaction and batch. Only realtime capabilities are excluded from the list. The key to the current large systems concepts is to do everything needed concurrently. Demand for large computer systems comes from both commercial and scientific users. Large corporations in the government (services, bureaus, etc.,) make up the bulk of large computer system users.

Some computer experts have questioned the viability of large systems in the era of distributed processing. The charges are that large systems are not responsive to individual users problems, and the conclusion is often the users would be better served if they had their own minicomputers. However, what appears to be happening is that users get their own minicomputers, or intelligent terminals, and promptly connect them to a large computer via a communications network (dedicated telephone lines).

Some depots may want to give thought to large systems and distributed processing. Distributed processing can include time sharing, computational resources for scientific users, protection of data base (software investment), and a host of batched processing. For most users, the preferred approach to distributed processing is to follow a hierarchical scheme with the large systems at the top of a group of smaller computers and terminals.

Design criteria for large computer systems include requirements for high speed, instruction processing, high speed input/output rates, the ability to address large fast memories, support for high-speed peripheral equipment and reliability.

No picture for the installation of new equipment is complete without a disclosure of costs. However, only some very rough indications of costs can be given until specific systems are finalized because of the wide variety of computers and peripherals available. A large-scale computer system ranges from 1 to 2 million dollars, monthly rentals range around \$25,000 (Auerbach Computer Technology Reports), and used systems are now available at sizeable reductions.

Minicomputers have made many significant advances since they were first introduced in the early 1950's. The minicomputer of today has greater power than many of the large computers of the 1960's and is very capable of handling such amazingly difficult assignments as APT--a language for programming 2-, 3-, 4- and 5-axis work. In addition to significant computing power, the convenience of placing a minicomputer physically near the job improves the user's ability to get a job done. Because of the simplicity of an APT or APT-like run on a dedicated minicomputer, one has the opportunity to better utilize existing support and part programming resources to increase productivity and reduce overall operating costs.

Microcomputers of the Digital, PDP-8, -10, -11 varieties range in price from \$25,000 to \$50,000. These are actually high capability type computers usually contained in small desk-type consoles that fit well in any environment (office, shop, etc.). Minicomputers, in this case, refer not only to the physical size, but also to memory and certainly price. By designing languages unique to a particular NC machine, such as a lathe, smaller 4K or 8K (8,000) memory units can do the work previously requiring 12K or 16K units. Such minicomputers range in price from \$5,000 to \$15,000.

Keep in mind that every bit of information that makes up the processor languages (part program, cutter paths and postprocessor) occupies some of the logic space in the computer. Unequivocally, if a computer has 32K words of memory and 30K are taken for the processor language, there remains only 2,000 words for part program processing. Thus, as minicomputers develop greater memories and increase their logic speeds, they will approach the capabilities of the larger computers. There is a trend to using a small computer for processing a part while all processor language storage is done on auxiliary units such as a floppy disc pack. Importantly, simple processors utilize smaller computers and simpler language, resulting in reduced costs; however, such computers are only applicable to the manufacture of the bulk of simple machine parts.

f. Controllers. Early in the development of NC machine tools, there was a clear cut separation between parts programming, control functions, and actual machine tool operation. The controller consisted basically of a set of relays, switches and timers that were set in operation from the electrical signals actuated by the punched EIA coded paper tape. The controller would then accordingly direct the movement of the machine spindle, the turning on and off of the coolant, the setting of the cutter speed, etc.

The controller usually was placed in near proximity of the machine tool or mounted directly on part of the structure. A number of controls common to the controller are found on the panel, such as, feed rate, feed increment, jog rate, tool offset, and start-and-stop.

As minicomputers became available, they were incorporated in the controllers and evolved into CNC controls. A look at the market today reveals that one is hard pressed to purchase just an elementary controller. Rather, the market offers a wide range of advanced and excellent controllers that provide any level of capability desired. For example, one controller, implemented with the latest microprocessor, is in every detail a graphics design-terminal plus CNC machine tool unit. With its own part programming language, a simple 2- or 3-axis part can be designed on its interactive display monitor, a cutter path computed and edited by recalling individual statements in error, the commands for the cutter paths generated in a corresponding EIA or ASCII paper tape or magnetic tape, the commands for the cutter paths placed in computer memory and, finally, a part produced with the NC machine tool from any of the recorded programs.

Nearly all of the more elaborate controllers provide a keyboard either on the panel or on a separate stand for manually programming the part in usually 2- or 3-axis. Clearly, many controllers have evolved into limited versions of graphics terminals. Such a wide variety of controllers will be of value when selections of equipments for the depots are made.

The completeness of the most advanced CNC units cannot be appreciated without listing the numerous features and options available to the user. Although such information is available from the CNC manufacturers brochures, it is important to present some of them at this time to provide an immediate basis herein for comparing systems and to show state-of-the-art developments for CNC machining centers. Of the roughly dozen leading CNC manufacturers, their machine centers usually have the representative following features:

(1) Physical and Environmental.

- a. Inclosure: sealed, vertical, operable to 120°F and 95% humidity.
- b. Power: 115V, single phase, 50/60 Hz.
- c. Size and Weight: 60-65 in. high, 36 in. wide, 32 in. deep; approximately 800 lbs.
- d. Electronics: modular, plug-in circuit boards, front and rear access, terminal boards for external electrical ties.

(2) Operating Functions.

- a. Axes: 3-axis with both positioning and contouring modes, circular/linear interpolation, optional 4th and 5th axis.
- b. Outputs: binary coded decimal (BCD).
- c. Storage: multipole block buffer.
- d. Feed Rate: 0.01-399.99 in./min., 0.1-9999.9 mm/min., programmable.
- e. Transverse Rate: 400 in./min., 10,000 mm/min., selectable.
- f. Dwell: g 04 code--0.0001-99.9 sec. programmable.
- g. Motions: inhibit for each axis, backlash positioning take up, reversal error compensation, rapid retrack to tool holder, dry run.
- h. Search Mode: forward and reverse for any coded number (N, H, etc.).
- i. Imaging: mirror of X and Y axes.
- j. Protection Circuits: error limit, synchronization tape and memory parity check, clock or feedback loss, overtravel, over-temperature, etc.
- k. Battery Power: computer memory battery back up.
- l. Diagnostics: built-in-test (BIT) circuits.
- m. Position: absolute machine tool position, light-emitting diodes (LED) display (X, Y, Z), trailing error.

(3) Data Input.

- a. Tape: automatic acceptance of both EIA tape codes, RS-244 and RS-358, ASCII (RS-358).
- b. Canned Cycles: turning, threading, facing, taper cutting, etc.
- c. Data: inch or metric.
- d. Commands: 999.9999 in., or 999.999 mm. max.
- e. Zero Suppression: leading or trailing zero.
- f. Programming: absolute or incremental.
- g. Position: preset any axis.
- h. Test Notes: dry run and tape test notes.
- i. Edit: loadable from tape.

- j. Storage: part program storage for one part program, editing and subroutines.

**(4) Features.**

- a. Operating Mode: manual, automatic, single, Manual Data Input (MDI), sequential number search, reference stop.
- b. Jog: high and low jog independently selectable.
- c. Incremental Feed: 0.0001, 0.001, 0.01 in., or 0.001, 0.01, or 0.1 mm., also 4 selectable rates.
- d. Feed Read Override: zero to 120% continuous, displaying.
- e. Manual Data Input: alpha/numeric keyboard can display select, offset/compensation entries, program edit.
- f. Display: alpha/numeric universal readout for display of machine data, error messages, memory content, servo lag, tool offsets and absolute machine positions, multiple CIT format.
- g. Zeroing: at reference, grid or present positions.
- h. Feed Hold: push button control.
- i. Offsets: sixty-four values to +99.999 in.
- j. Path Retrace: cycles for single and multiple block.

**(5) Optional Features.**

- a. Adaptive Control: tool load-sensing control.
- b. Program Storage: storage and computer memory - up to 10 programs.
- c. Automatic Compensation: tool length, cutter diameter and part misalignment.
- d. Program Edit: stored or tape-reader programs.
- e. Fourth Motion: positioning and simultaneous contouring.
- f. Voltage Transformer: multiple input --  
200/220/230/240/380/415/440/460/480/555V.

In summary the surveys showed that essentially three different kinds of controllers are used in a system:

(1) A controller stripped of computer-aided control and limited to the earlier basic manual controls is tied to a machine tool. The integral paper tape reader accepts control tapes developed by a separate independent parts programming facility such as described in System I.

(2) A greater capability controller having microprocessor based control, manual programming capability, editing features, operation of the NC machine tool from paper tape or computer memory, becomes an integral part of the machine tool.

(3) A total stand-alone minicomputer-aided controller having the capability of parts designing, programming, editing and commanding the NC machine tool operation is part of the NC machine.

As a final comment on controllers, a review of numerous manufacturers' brochures on controllers of all kinds shows that a wide range of capabilities and options are available with no apparent standardization of features either in hardware or software, with the one exception that they all accept EIA coded machine control tapes.

g. Adaptive Control. There is some mystery of what is meant by adaptive control (AC) as it applies to NC machine tools. Adaptive control is simply an electronic feedback system that supplements the existing feedback network of the NC system in order to improve or optimize its operation. This is analogous to an individual's brain which can readily acknowledge body temperature and stress changes being fed back to it by the nervous system. Of course, the individual can make decisions on how to react to these changes. Adaptive control units are supplied as separate small add-on boxes which operate in essentially a parallel arrangement with the existing feedback lines of the NC machine. Relatively few companies are found to manufacture such adaptive control units as compared to those building CNC units, nor is there any explanation given of why the manufacturers do not at the outset integrate adaptive control in their CNC control product line, especially when the advantages are supposedly so valuable.

Adaptive control leads to production improvements through automatic sensing of the changes in the machining process, which commonly include torque, force, temperature, vibration and tool wear. These sensed changes in the form of electrical voltages and currents are fed back to the adaptive controller so that appropriate changes can be rapidly computed and executed. For large volume NC machining, the application of adaptive control results nominally in 10 to 30% increased productivity where optimum machine conditions mean more part output each day at a lower cost per part. Further savings are found in reduced tool breakage and associated costs of machine down time, extended tool life and lower maintenance costs for machine tool abuses.

Add-on adaptive control systems are applicable to milling work, but particularly more so to drilling operations. For drilling, for example, such systems provide electronic control of the drilling cycle on the NC machine tool on which it is used. It increases productivity by maximizing machine feed rates without motor overload. Such control systems are adaptable to machine tools for drilling, boring and reaming, and having electric or electro-hydraulic control of the Z-axis feed rates and electric motor driven spindles where torque is critical.



The system works as a sensitive feedback network, the degree of precision is a function of the sensing elements and processing system. The system electronically senses horsepower, calculates the torque exerted on the drill, and automatically varies the spindle feed rate to obtain the highest penetration rate obtainable under existing drilling conditions and within the proper loads for the drill, to prevent breakage, limit dulling and temperature rise. Spindle rotational speed, maximum feed rate, and drill torque limits are computed usually by a minicomputer processor program from drilling data taken from limits tables by the part programmer. In other words, through adaptive control, the drill operates optimally within the bounds selected by the design engineer.

For the regular NC machine tool system utilizing the APT part programming language, adaptive control system instructions generated by the processed feedback signals are automatically inserted onto the tape at the proper location for each drill or tool used. For most adaptive control units these instructions are machine independent. The adaptive control system calculates new instructions to be compatible with the machine speed, feed rate and low capacity. For a typical drilling operation, one adaptive control system eliminates the need for looking up feed rates and spindle speeds for writing instructions in the part program; rather, the programmer needs only to give the part material type and strength, drill material and size, and type of coolant flow; however, certain critical limits, torque, feed rate, etc. can be given. For such a system as System I, which uses APT, the programmer inserts adaptive control in the APT part program, then the preprocessor program in the large computer produces the correct instructions for the cutter paths, and with the designated postprocessor an appropriate paper tape is produced.

Aside from the operational features described, there is another aspect of adaptive control that the average users of NC machine tools find rather vague. This deals with the sensors required to produce the error signals to the feedback loop. Strain gage sensors mounted on the spindle measure spindle torque; tachometers on the spindle and the table feed motors provide rotational velocities; quartz crystal accelerometers provide vibration signal data; and the tool temperature is measured by the natural thermocouple effect caused by dissimilar metals--the tool and the workpiece. The changes in the voltages and currents produced by these sensors in their electrical bridges or amplifiers provide the error signals for the feedback input to the controller.

h. Training. For this section, the goal is to air discussions, facts and ideas on the training of personnel for the operation of NC Intelligent Hardware. Specific details on training are best left to the section dealing with training.

The training of personnel to operate the Intelligent Hardware as part of a total NC machine tool system, is a function of the complexity of the

part to be produced and the kind of NC machine tool system involved, such as the system previously described as System I.

In conversations with part programmers at Air Force and Navy depots and technical representatives of NC hardware companies, one hears statements like this, "We can train a person to do part programming and operate our system in two to three weeks, if he has the right background." Interestingly enough, this is a true statement. It is true for producing the bulk of simple 2- and 2½-axis work or for working in simple NC machine tool systems where the programming language and hardware have been specially adapted to a particular computer, controller and machine. However, validity of such a statement is dependent on the available candidates to be trained. He must be experienced in parts design, parts materials, and machine processes and methods; furthermore, he must have an adequate mathematical background. This appears as a naive statement. A person with such qualifications is not the run-of-mill type candidate, but one who has had many years of training and experience in machining and allied areas. Yes, such a person can be sent to a company or Army training school and within two to three weeks do simple part programming and operate an NC machine tool.

A clarification of where such limited training is adequate needs to be reviewed. Most current and advanced CNC machine tools offer this opportunity. A parts programming keyboard is either on the controller panel or on a remote terminal. The CNC manufacturer has developed a simple programming language along with canned cycles to further aid the programmer. Editing is done interactively by using the minicomputer in the CNC unit. Finally, the last step of processing the input instruction to output commands to run the machine tool is included in the system. Clearly, two to three weeks of extensive training by company schools or the United States Army Management Engineering Training Activity (AMETA) qualifies the trainee to do part programming and operate a CNC unit. Of course, it is understood that the trainee has the qualifications given in the preceding paragraph. Certainly a trainee of lesser qualifications would still be trained sufficiently to program and machine many of the simple 1- or 2-operation parts, e.g., drilling a few holes in a flat sheet.

Various people in control of NC machine tool systems belabor and garble the mathematical training required by stating that the trainee needs courses in basic mathematics, algebra, and plane and solid geometry. What is truly important is not that the trainee has had these courses, but rather that he can apply them accurately to part programming and to computing rates and loads, etc. However, the successful completion of such courses and most importantly with on-the-job (OJT) training, he can more rapidly achieve the desired end of becoming a proficient part programmer and NC system operator. The time involved, how-

ever, is not just a mere three weeks, but considerably longer depending heavily upon the trainee's previous experience and education.

A few comments are necessary in regards to manual programming training. With interactive graphics and the new CNC machine tool systems, the need for manual programming using the older EIA machine code is being replaced by the many new programming languages developed by the manufacturers for their new NC machine tools. Furthermore, it does not take the manual programming of a very complicated part to soon appreciate the need of a computer to do the required computations.

Consider now the training needs for a comprehensive, high speed, high performance system using the APT language. No longer are machine parts largely of the simple 2-axis variety, but involve very complex contoured parts requiring simultaneous cutter movement in 3 axes. Such are the part programmer problems for System I which uses a large computer and the APT part programming language. Here a part programmer needs considerable expertise in programming in APT, as well as, an extensive and in-depth background in materials, machining and mathematics. To be able to visualize the machine tool paths for a doubly contoured surface, a person requires considerable experience in the use of three-dimensional geometry. A person of this calibre represents a considerable investment by a depot for his training. Nor is there any short cut that can be taken in the training process. Furthermore, at least two such part programmers are necessary at a facility to take care of the complex parts even though such parts may represent, say, 20% of the NC machine tool workload. One part programmer is needed for backup.

The problem of training personnel for NC machine tools is well understood and covered in nearly all text books as well as special documents on Numerical Control. Excerpts are quoted in the appropriate following sections on training recommendations along with additions derived from the information gathered from the military, government and industry.

4. SUMMARY AND CONCLUSIONS. For the Army Depots located throughout the United States, the important goal strived for in this section on Summary and Conclusions is to point to a standard NC machine tool system that can be adopted by each depot. Such a system must be standard but versatile in all elements of its structure so that either a "starter" system or more complex system can be recommended to the particular depot under consideration for the installation of the NC machine tool system. A standard starter system is defined herein as one that is designed for future expansion without the need of special equipments or total system modifications. The system is bounded but expandable and provides interchangeability from depot-to-depot due to the standardisation of the units.

Digressing a moment, the interpretation of "standardization" has received much attention and has been the center of much controversy. One

company poses the problem quite clearly, "standardization is important but sometimes it is just not practical to standardize. It is a good objective, but if you really pursue standardization, you're likely to end up hurting yourself."

First, one needs to bring the findings presented in the preceding sections into focus so that conclusions can be made, thus it is necessary to reiterate the purpose, or goals, of this study which are as follows:

(1) To present actual data on intelligent hardware used successfully on NC machine tool systems over the past fifteen years, but mostly for the recent few years when solid-state technology was applied to such systems.

(2) To make predictions on improvements and changes to expect of NC machine tools in the near future (1980) which will effect recommendations.

(3) To make recommendations on the kinds of NC intelligent hardware to purchase (the recommendation will be heavily dependent on the kinds of machine tools selected).

(4) To present information and specifications on intelligent hardware: computers, controllers terminals, readers, plotters, etc.

An extensive review was made of the pertinent facts on the kinds of intelligent hardware available, their capabilities and limitations. Their application to three actual, but considerably different, NC machine tool systems were analyzed, starting with a total high capability system and ending with a minimal system.

Without any reservations, the high capability system, designated previously as System I, meets all the requirements specified by the Army for "readiness" (The ability to independently machine any complex part required for a maintenance job at a depot.) Not only does this system meet all requirements, but it is currently both successful and operational at a number of Air Force and Navy facilities. The system is programmed in the APT language which has been designated as the international standard NC machine tool language and the designated standard for the Army.

Without proceeding further, the analysis clearly indicates that System I should be recommended for each depot. The installation of such a system, though excellent and desirous, is definitely an over-kill for most depots, and most importantly, the price tag of 1-2 million dollars for the system is too high for a single depot to handle; however, if it is split between four depots the cost is nominal. Certainly, such a system would be entirely feasible for a number of depots located in the same

geographical area. This system has a major shortcoming since a destruction of the central computer under any circumstance inactivates the system for providing any new parts programs; it is clearly a vulnerable system. Certainly any part EIA tape in the repository can still be used on the machine tool for which it was processed; however, this is of little utility unless such a part happens to be needed. The probability of such an event is extremely small.

As is now readily apparent, the advantages and disadvantages of Systems I, II, and III need to be compared in conjunction with each depot's present and projected needs. This is best done by constructing a table which lists the important characteristics, features or associated requirements which were collected in this study. Such information is given by Fig. C-8, "Comparison of Systems I, II, and III." This must, by necessity, be a tentative set of comparative data since additions, modifications and deletions will certainly be forthcoming after the individual depot's needs are finally reviewed in order to make firm decisions on the kinds of NC machine tool systems that need to be installed.

A survey of the depots' needs for NC machine tools indicates that all twelve depots, with the exception of one depot, are candidates for the so-called starter NC machine tool system. Some of the depots now have a few NC machine tools of the 2 to 3-axis variety with plans for the purchase of a few more, or no more, units over the next five years. A survey has been made by the NC Study Group Visitation Teams, May 1979, and recommendation for NC machines were determined for each Army Depot. See the section on Overall Concepts, Fig. H-2.

The starter system has some truly attractive advantages and can lead to a productive, totally versatile and cost-effective system. It embodies two key features: low cost and nonvulnerability.

To place a starter NC machine tool system in a proper light so that it can be treated objectively, an example of a realistic system is reviewed, including all the details, advantages and disadvantages. Unlike software, the hardware selected for such a system becomes a capital item. It must endure over the years. As such, it must be expandable and reliable. Furthermore, every effort should be made to automate the system taking man out of the loop for all possible operations. One of the key benefits of an automated system is the consistency of the work that is turned out. Mil-Specs are achieved every time. In addition, such a system should have the largest number of configurations possible by using flexible modular system design. Such a system is depicted by Fig. C-7.

Notice that this is an expandable system that brings into play the computer to aid in every activity possible; potential savings are high. Standard computer peripheral devices plus other large computing systems are found to be easily interfaced with such a basic system. This simply

means that if at a later time it would be advantageous, two or more depots could combine into a network such as the one previously described as System I. Such a system through the use of dedicated telephone lines can provide an access to each other's data bases, the use of centralized on-line high speed plotters, and to central archiving of the data files.

Depots apparently fall into one of the three general categories in terms of available NC machines in their shops: (1) those that have essentially none at all; (2) those that have a few (2 to 3); and, (3) those that have a considerable number (3 or more). The study showed that no depot even closely approaches the number of NC machine tools found in industry; consequently, operations could not be compared on a one-to-one basis.

Those depots having but a few NC machine tools, or none, could consider starting with a minimal system which basically includes a Flexo-writer for manually writing the part program and punching the NC machine tool control tape. These NC machine tools could be lathes and mills with controllers such as shown by Fig. C-7. The included NC machine tools would have basic, simple-controlled units such as found on the earlier models dating back to 1970. The reasoning behind choosing an earlier model and discussing a minimal NC system is twofold: (1) it is related to older units presently in operation that need to be included in a depot analysis, and (2) it provides a framework for comparisons with the newest products on the market with their many improvements. None of these comments or observations could be construed at this time to imply that a minimal system is best suited and most cost-effective for every candidate depot.

At the outset, an analysis of the main features of the system, along with its limitations, is important in pointing out whether or not a minimal system would be applicable for installation at a depot.

First, and most importantly, the system is limited to the programming of simple parts. This statement calls for an explanation of what is a simple part. This is best done by considering the machine operations involved. Therefore, consider the NC machine spindle which can be manually programmed to move from point to point in one plane, say the XY plane. Normal Z axis movements are not continuous, but are set beforehand by cams to the required values. Such control of the spindle allows drilling, reaming, etc., of holes at various locations for any casting or block of metal. The bulk of such operations is quite common for machining sheet metal parts. Milling pockets and contouring of castings become increasingly more difficult to program, and it soon becomes a revelation that the assistance of a computer is imperative to make involved tool-path computations. There is a point soon reached where computations become so specialized and involved that program cycles (referred to as canned cycles) have to be computed beforehand by programming experts.

Without equivocation, manual part programming is seriously limited in scope, slow and tedious. On the other hand, however, a person with an appropriate background in machining and lots of experience in manual programming can rapidly part program a large number and variety of simple parts. This may appear as a naive statement; however, our studies show that such parts constitute from 40 to 80%, and more nearly around 80% of the work encountered at a depot. This appears gratifying if one does not consider the total capability requirement requested by the Army which requires that any part encountered in the maintenance workload of a depot, regardless of complexity even though they represent a small part of the total workload, can be machined. This requirement has been shown not to be feasible or practical and has been relaxed to the degree required by each particular depot.

To better understand the workings and utility of this system, let us investigate next the specifics of another one of its major components-- the NC machine controller.

Starting with the control panel, this unit usually has the machine operator manual master start-and-stop pushbutton switches to actuate the drive motors, hydraulics and power relays. Continuing, two other switches provide "cyclestart" and "cycle-stop." The machine control tape can be reviewed by pressing the cycle-stop pushbutton and restarted by the cycle-start pushbutton. Another operator manual control is the cycle selector switch for drilling, boring, tapping, and milling. These are common preparatory G functions, or sequences, wired into the control unit that can be called up by the tape. These functions make parts programming easier since they even include interpolation routines. In a sense, they provide a computer-type advantage to the programmer since they are truly programmed operations placed into the controller hardware. Other switches provide manual or automatic tape control of the operation, such as the search feature which provides a means of backing up to a previous sequence number. Even a parity LED light provides a means of checking the tape by dry running it on the reader. Zero shift switches provide a further refinement by allowing the origin of coordinates (X, Y) to be positioned as required. As mentioned, the spindle is preset for a job by a number of cams to the Z depth required for machining the part. These depths are programmed by identifying the cam number which corresponds to a depth displacement command by the controller.

The procedure to write a point-to-point part program is straightforward and is usually done on a Flexowriter typewriter keyboard. Each instruction keyed in by the typewriter is translated to the EIA code and then punched into the control paper tape. The completed control tape can then be taken to the machine tool, placed in the tape reader, and turned on to run the machine. Note, the operation is quasi-automatic with an operator required to intercede to change speed rates, reset the origins, change tools, etc. Definitely, the amount of interaction necessary by

the part programmer or operator is governed by how many refinements were built into the total system.

By summarizing the advantages and disadvantages, an assessment can be made of the minimal system.

Advantages:

1. This is an operational system requiring only a minimum number of parts: (a) NC machine tools with basic controllers, (b) a Flexowriter for manual part programming with associated paper punch, and (c) such peripherals as tape storage cabinets, etc.
2. The system is expandable. Any number of NC machines can be added.
3. It covers 40 to 80% of the parts encountered in a maintenance depot. These are the 2- to 2½-axis variety.
4. Standard EIA/ASCII machine-controlled tapes are produced.
5. The system is low-cost. The Flexowriter, two NC machine tools and accessories cost nominally \$120,000. (A Flexowriter is valuable to have around for repairing or correcting tapes.)
6. Minimum training is required, varying from three to ten weeks and depending on the trainee's background.
7. A minimum system requires minimum maintenance.
8. NC machine tools already existing at a depot can be included in the system.

Disadvantages:

1. Probably the main disadvantage is that the system does not meet the continuous 5-axis capability required by the Army for readiness. The requirement, however, has been almost totally relaxed.
2. The parts programming is slow and limited to 2½-axis work.
3. There is no interaction with the controller for part programming, editing and design.
4. There is no computer-aided capability.
5. The concept is archaic and does not take advantage of important advances in NC technology.



6. There is no computer storage to allow the program to run from memory so that one does not have to worry about the paper tape wearing out or being damaged. (Computer storage allows storing up to 20 or more programs.)

Another approach to a minimal system is the purchase of stand-alone CNC machine tools. Such units can be purchased that are complete in every detail. A control panel on the controller has all the manual operation features mentioned above plus a number of other extras that results in a more versatile and higher capability unit. A keyboard similar to that on a Flexowriter is found on the panel which permits manual parts programming and tape editing at the machine tool. For editing, this has the advantage of the operator being able to stand by the part being machined, where direct observations of the machine can be made, and necessary corrections can be inserted on the control tape. At all times during the machining, the tool location coordinates (X, Y, Z) are displayed to four places by large LED readouts on the panel, thus providing a check of the part being manufactured.

Not only can one do manual part programming on the modern CNC units, but some offer interactive graphics whereby parts can be designed directly at the control panel (see Fig. C-9). The minicomputer included in the total package increases the overall capability whereby the part programmer can interact with designing and editing of a workpiece. The part manuscript, the cutter paths and the final machine control program are all done at the controller. The program can be viewed and checked at any time on the CRT. Another key feature advertised by the manufacturers of such units is tapeless control of the NC machine tool from programs stored in computer memory. Such a unit is truly a CAD capability designed into a stand-alone CNC machine tool.

Some of these CNC machine tools have built-in postprocessors and provide automatic programming. For example, all the operator has to do is to enter the basic dimensions of the workpiece, the codes for the tools to be used, offsets, feeds, speeds, and the built-in computer software makes all necessary computations and programs itself. G codes and arc centers do not have to be programmed.

The software of such units include CAD cycles and program copy (repeats the program at other locations). Some units have special languages using actual English words thus eliminating the need for a program specialist. Program editing is extremely simple because all operations can be checked by displaying the graphically simulated generation of the tool path of the finished part profile. After a few hours of familiarization, the average machinist can learn to use the automatic programming system to program a part. Most errors are immediately apparent on the CRT display and result in less scrap losses.

CNC machine tools of the closed-loop variety (lathes and mills) are available for 2- and 3-axis work. The degree of sophistication of these units needs to be determined by the user. There is a wide variety of CNC machine tools offered by the manufacturers today. The matching up of depot requirements with available CNC machine tools would therefore become a future task.

To provide a basis for evaluating the use of CNC units in a starter system, the same procedure followed before in presenting advantages and disadvantages is offered.

Advantages:

1. A depot can purchase a CNC lathe or mill, one at a time, as the need dictates, and so build up its NC capability. This is a progressive method requiring a minimum outlay of funds.
2. Each CNC machine tool stands alone. This means that each installation is complete for the design, programming and production of a part.
3. Minimum training is required since the unit has the major advantages of the included minicomputer and interactive graphics.
4. The system has 2- and 3-axis capability.
5. Interactive graphics increase the versatility of the system providing a design feature, reducing the time for part programming, and providing editing of a part.
6. Parts are run from computer storage thus eliminating paper tape wear and damage. As many as 20 programs can be stored and recalled as needed. All outside programmed EIA/ASCII tapes can be run on the built-in tape reader; furthermore, these tapes can be edited and corrected.
7. There are claims of reduced space and storage cabinet requirements.

Disadvantages:

1. The main disadvantage here could be cost. The advantages of such a system versus cost need to be weighed for the application considered. The nominal cost of a new closed-loop tapeless CNC lathe control with graphic display and simplified automatic software programming is \$180,000. A 3-axis mill with the same capability is nominally \$150,000.

2. The system does not meet the continuous 5-axis capability required by the Army for readiness.

The two separate starter systems, one with minimal hardware, a Flexowriter, and one or two NC machine tools, and the other with the added capabilities of interactive graphics and automatic programming were branded as limited or inadequate. If one takes the best parts of these two systems and rectifies the inadequacies, there results a total system truly worthy of support and recommendation. Evidently, the same apparent observations were made by a number of companies because their newly developed intelligent hardware and associated systems have surmounted the above-mentioned problem areas. What was really lacking in the second mentioned starter system was a minicomputer with software to provide the computations imperative for a 5-axis capability. By assembling a special and select group of NC components as depicted by the expansion system in Fig. C-7, not only has a high-capacity and high-speed programming capability been developed which meets the 5-axis criterion, but also a bonus has been attained by having a real CAD feature added to the system.

The main stumbling block in meeting the requirements for a total and qualified system is the computer. Previously, an adequate computer had to be of the large-scale variety until the recent advances in minicomputer hardware and software have converged on the capability and speed of the number crunchers such as the IBM 360-65. Such a minicomputer is found to be a main part of the expansion system in Fig. C-7. There are APT-based languages especially designed to run on minicomputers which are compatible with their processors and all of their postprocessors. Most importantly, they will handle the difficult 5-axis part programs. There were some 25 computer and electronics companies reviewed in the study that manufacture minicomputers to easily fit these requirements.

A brief description of the expansion system, which includes interactive graphics as it relates to a part to be designed or taken from a blueprint to the final machining, reveals its versatility, simplicity, and total capability. Additional descriptions of this system concept are given in another part of the report under the topic of CAD/CAM.

Starting with the visual monitor (CRT display) and the integral design keyboard of an interactive graphics terminal, the programmer can directly design a new part, line-by-line, hole-by-hole, and contour-by-contour by interacting with the graphics unit and its interfaced minicomputer. For example, the programmer keys in the coordinates of a single line as designed; this line in turn is automatically displayed on the CRT, then a numbered set of further designed instructions are presented on the CRT. The programmer then selects the desired instruction and keys in the indicated number. By this interaction, the entire part can be designed with the aid of the graphics terminal and the mini-

computer. The final design viewed on the CRT can be automatically dimensioned. Throughout this whole process, the minicomputer signals or rejects improper instructions, thus providing a very rapid and foolproof editing procedure; furthermore, the designed part can be displayed on the CRT in the three standard drafting views or in three-dimensional isometric. By directly viewing the displayed part, errors can be rapidly identified and corrected.

A drawing can be copied from a blueprint or sketch in a similar way. At any place in the design or part copying process, the programmer can press a key and have a 8½ x 11 in. hard copy made of the part or the computer instructions which are displayed on the CRT. At this place in the process, the programmer can request the minicomputer to display and print a hard copy of the part manuscript which is very similar to the part manuscript prepared when using the APT language without the aid of a graphics system. This CRT-displayed information will be very similar since an APT-based language has been used.

So far, the amazing aspects of this system have only been partly revealed. The next major step in part programming is to have the cutter paths determined for the different size milling tools, drills and other machining operations. Here is where this system really helps the programmer. By picking the proper tool and the specified tolerances, the minicomputer computes the center line path of a cutter from its start to final position for each operation. Most importantly, the cutter paths are displayed in any of the standard drawing or isometric views. Here again the programmer can interact with the minicomputer to optimize the machining of the part. Expensive mistakes of positioning or moving the tool into the base plates of an NC machine tool can be avoided by direct viewing of the cutter paths on the CRT. The cutter path (CLPRNT) instructions can now be displayed for the total operation and an 8½ x 11-in. hard copy made.

The best feature of this system is yet to come. By merely depressing the proper key on the keyboard, a postprocessor language is called up to change the CLPRNT data into an EIA/ASCII paper or mylar tape for operating an associated NC machine. Presently there are postprocessors for practically all the NC machines on the market. The postprocessors found at a depot are included in the total system and can be called up any time for the NC machine tool to be used. Finally, the actual machining instructions can be displayed on the CRT and corresponding hard copies made for the record. Thus it can be seen that the same instructions typed by a large computer system using APT are obtained by this expansion system; namely, (1) the parts manuscript, (2) the cutter paths, and (3) machine tool commands.

As additional funds are obtained peripheral units can be advantageously added to the expansion system. One of the first units that would be attractive to most depots is a high-quality, high-speed plotter, allowing all standard drawing forms up to the E size to be made from the drawings by the first phase of the part program. High speed drum plotters can produce drawings in minutes. Plotter accuracies of 0.004 in. are stated by the manufacturer. Such plotters represent the state-of-the-art developments. The time from the design of a fairly complex part to the final working drawing takes from two to six hours depending upon complexity of the part and the proficiency of the programmer.

Other peripherals to improve system operation would be additional computer storage (core, tape, disc, etc.) to allow storing a large number of machine controlled programs for machine parts directly from memory, optical scanners for copying part drawings in computer memory, and a variety of tape readers, etc.

As the work load increases, separate graphic design terminals can be added to the system. Each terminal can be supplied with a separate minicomputer so that there is no need for time sharing with the main computer. This way there is no limit to the design terminals that can be added to the system, and each terminal operator can design at a fast pace without waiting for the computations to be completed for the other terminals.

Another versatility of this system is that, with the addition of proper interfaces, the data can be transferred by dedicated telephone lines to remote data bases, high speed plotters, and archives. The capability of exchange of data between depots expands this system into the model given earlier as System I.

As before, the advantages and disadvantages are listed to provide a basis for recommendations.

#### Advantages.

- (1) Parts of 5-axis machining (supposedly of any complexity—doubly contoured surfaces, rotation of axes, etc.) can be designed and programmed with the aid of the graphics terminal, minicomputer and the self-contained interactive programs.
- (2) Drawings of parts can be transferred to the visual monitor and programmed for machining up to 5-axis.
- (3) A part manuscript, CLPRNT and NC machine tool commands are available on the CRT monitor or on hard copy for the record.

(4) The NC machine can be run by paper tape or from computer storage. Some 20 programs can be stored and called out separately to machine the corresponding part. Thus, tape wear and tear are no longer problems.

(5) Simplified APT derived languages are used.

(6) Any number of postprocessors can be included in the system.

(7) A part can be designed or taken from a drawing and a program generated to produce the NC machine tool control tape or placed in memory, in nominally four hours for the usual 2- to 3-axis part.

(8) Hard copies, 8½ x 11-in. are available for any drawing, program or information appearing on the CRT.

(9) Standard drawings of sizes A to E of the designed part are readily produced on attached high speed plotters.

(10) Cost to run such a system is 1/20 that of those required to use APT.

(11) Any one of a large number of minicomputers are compatible with such a system.

(12) Any number of graphic terminals with their own minicomputers can be added as the system demands grow.

(13) The programmer can learn to design, program and operate the whole system in two weeks.

(14) The entire system can be placed in nearly any area. No special air conditioning, temperature and humidity controls are required. Certainly, a clean environment is advantageous.

(15) The system is essentially maintenance free; however, all companies provide periodical preventive maintenance at standard rates.

(16) The minicomputer can be used for business or scientific work on "off" times.

(17) The graphics terminal replaces the drawing board and the plotters replace the draftsman and copiers.

(18) Numerous large companies (aircraft, automobile, machinery, etc.) are rapidly converting to systems with 10 to 20 graphic terminals or more.

### Disadvantages.

(1) Cost of a complete system with three graphic terminals, mini-computer and average number of peripherals is around \$200,000.

The advantages of this system by far outweigh the disadvantages. Evidence to this effect, however, comes from the fact that large companies are rapidly replacing the drawing boards with graphic terminal. The responses from users are highly enthusiastic. Even though this is not quantitative information, the momentum of the technology in the direction of graphics has real significance.

The study to date has not revealed any clear-cut concise cost analysis of the so-called expansion system. To add further credence to such systems, a tabulation of positive features in favor of this system is presented. These are:

### Expansion System Justification

<u>Item</u>	<u>Percentage Change</u>
Machine Tool Use	10 to 25% Increase
Programmer Efficiency	5 to 100% Increase
Scrap and Rework	10 to 20% Reduction
Turn-around-Time	100 to 400% Faster
Accuracy	5% Improvement
Gross Errors in Programming	10% Reduction
Reruns Required	10% Reduction
Program Quality	10% Improvement
Desk Checking	10 to 25% Reduction
Continuity of Thought for Programmer	100% Greater
Low-Cost Training System	5 to 50% Reduction
Program Tapes Optimized	5 to 10% Reduced Tool Time
Proofing	5 to 10% Reduced Tool Time
Waiting for Tapes	10% Reduced Tool Time
Part Quality	10% Improvement
Lead Time	10 to 20% Reduction
Machine Maintenance and Repair	10 to 20% Reduction
Production Control	2 to 5% Cost Reduction
Better Use of Manpower	10% Improvement
Reliability of Parts Produced	30% Rework Reduction
Savings in Setting and Maintaining Standards	30% Reduction of Standard Costs
Scheduling Savings and Flexibility	10 to 15% Cost Reduction
Inventory Lead Time	10 to 25% Reduction

### Expansion System Justification

<u>Item</u>	<u>Percentage Change</u>
Inventory Reduction Due to Shorter Queues	5 to 20% Reduction
Material Handling Costs	10 to 20% Reduction
Quality Control Improvement	10% Reduction of QC Costs
Longer Tool Life	20 to 30% Reduction of Tool Costs
Savings in Tool Purchasing	5% Reduction of Tool Costs
Tool Life	20% Increase
Tool Inventory	10% Reduction
Tool Maintenance	20% Reduction of Grinding Costs

The section would not be complete in its analysis without presenting the details of the remote large-scale APT system designated as System I since it is not unreasonable to speculate that it may be the system that best fits the needs of the depots. A brief exposure to System I has been given previously. A reiteration of some of its important characteristics provides a basis for further investigations and comparisons with the attractive above-mentioned minimal system. System I has a large high-speed and high-capacity computer located remotely which can serve the needs of a large number of depots on a time sharing basis. Terminals at the various depots communicate with the central computer via dedicated telephone lines.

The computer operating from the APT language processes the input part manuscript information by syntax checking, part program decoding and simple and canonical form table setups and execution of arithmetic statements and surface definitions. After all calculations and surface definitions have been performed, the motion commands are performed which result in a central line file. This output becomes the input to the postprocessor. The postprocessor is a program written in a language compatible to the computer which then transforms the cutter path information into control commands for a particular machine. Any number of postprocessors can be stored in computer memory where each postprocessor corresponds to a specific type and make of NC machine tool located at a depot. Postprocessor output is such that a paper or mylar tape can be punched in EIA or ASCII code to operate the machine. The manuscript, cutter line path, and postprocessor output programs can be typed out at the originating depot, thus providing a written record of the entire part programming process. Each of the three programs can be reviewed, edited or changed as required.



Each depot has to analyze its operation to determine the number and kinds of peripheral equipments it requires, as well as other support items or facilities. One particular Air Force depot visited had rather a comprehensive NC machine tool facility. First of all, a separate room housed a number of flat tables for spreading out large drawings. These drawings were analyzed to write part manuscripts in the APT language. Hand calculators and a library of technical manuals, APT programming data, materials, machine processes and peripheral instruction manuals, etc. were readily available. Three highly trained and experienced programmers did all of the parts programming, editing and changing of programs. A change in a program was definitely not permitted by the machine operator. The reason was well justified. To chance major damage to a \$100,000 NC machine by an inexperienced operator is unwarranted and inexcusable.

Other peripherals in an adjacent computer room included a reader for the familiar computer-punched card decks on which the part program manuscript had been transferred by a keypunch technician. A control terminal with a typewriter keyboard was part of the complex and was used to interrogate the remote large-scale computer to read in the part information to its compiler or processor. A local high capacity storage unit using magnetic tape or floppy discs is required to enter the card deck data and processed data returned by the remote computer so that programs are not lost and can be recalled for modification. A certain number of complex computations have to be handled locally, thus calling for the addition of a minicomputer. To use the remote computer for incidental but necessary calculations would be unwieldy on a priority time shared basis even though the actual computation time may only take a few minutes for a particular problem.

Found in the computer room were paper and mylar tape punches that could take the data from the remote computer directly or from local storage to produce the NC machine tool control tapes. Activation of the tape punches, as well as the other peripherals, was keyed in on the typewriter keyboard of the main control terminal.

Flexowriters with attached paper tape punches were available for the correction and duplication of tapes and some manual programming of simple parts. They were stated to be a valuable item to have around.

A separate tape repository was available in the tool room. All control tapes were identified by code so that they could be recalled for use at a later date.

To consolidate the workings of this system, an example of how a part is programmed is explained from the initial reading of the blueprint to the final removal of the machine part from the NC machine tool. Such a procedure allows the merits of this system to be determined. The

manufacture of a part starts with a dimensioned print of the part, such as a check blueprint. Consider a complex part that includes a warped surface, a number of recesses and repetitive holes and patterns. The experienced part programmer will spend as much as three days in developing a strategy by marking the print of the departure points, circles, arcs, etc. to minimize the tool operations, part relocations, computations and overall machine time. With the aid of the IBM 360 APT NC Processor (360A-CM-10X Version 4) Part Programming Manual, or equivalent, the involved and tedious job of writing the part manuscript is started. For a complex part, it is not uncommon to have the manuscript contain 50 to 100 APT program sheets. Contrast this operation with a graphics terminal where the manual writing of the manuscript is done automatically by the software of the system.

Being satisfied by the part manuscript, the programmer hands it to a computer technician who laboriously converts the manuscript to the well known computer cards with a card punch. The cards are then placed in a card reader for transmittal to the remote large computer via dedicated telephone lines. The first card identifies the requesting depot, the job number and required postprocessor.

The next step is the execution of the program. The computer is addressed by a terminal by keying in the proper commands. This was a time-shared system where the subscriber utilized the "number cruncher" to the limit by doing scientific computations, inventory and NC machine tool program processing. The computer works on priorities. Certain classes of data would take precedence over others. This means that the computer could not accept card information immediately, and it could take as much as 30 minutes to activate the card reader. After the card information is transferred to the remote compiler, the message of the read-in time and the priority of the part is typed at the depot terminal. All jobs in the network, with their priorities, are also given so that the programmer is informed of the delays to expect. One operation took 51 minutes before the job was completed even though the computer probably took only three to five minutes of this time. A history of processing times showed that the job rarely took more than two hours of turn-around time. Incidentally, the history of each operation is recorded on a yellow-paper copy produced by the terminal typewriter. At the depot, the data returned from the main computer are stored and called out to produce the tape for the designated NC machine tool. The machine tool program can be typed for review. A final typed statement gives the machine time and length of tape.

Finally, the tape is taken to the shop, placed on the NC machine tool controller and a test part manufactured by using a block of wood or plastic. Any errors found are referred back to the original manuscript or appropriate computer program for correction. The programming sequence given above is repeated to produce a corrected tape.

All the system lacks are graphic terminals. However, with the proper interfaces to the computer any number of graphic terminals can be added. In the case where there is a minicomputer at the depot of the FDP-11 variety, or equivalent, the necessary computations could be generated locally without the need of the remote computer. Tying into the main computer for such operation would not be feasible anyway since the main computer usually is on a priority basis rather than a true time-sharing basis. A designer would not want to wait, say five minutes, for a graphic keyboard input to be processed by the computer. Now, with the further addition of plotters as described for the expansion system, the system is certainly highly versatile and comprehensive.

The same procedure as before, in listing the advantages and disadvantages, allows an evaluation of this system.

Advantages:

1. The main advantage of this system, beyond any question, is the capability of programming a part of almost any complexity and reasonable size. Of course, the NC machine tool must have a corresponding capability, such as, appropriate table size, continuous table movements up to 5-axis, required tool changers, etc.
2. Actual computer time is around five minutes for a nominal part. At \$840.00 per/hr, this is only \$7.00.
3. Since the part programmers work separately to develop a part manuscript, the remote computer is not tied up in interactive communications between programmer and computer.
4. The system satisfies the Army readiness requirement.
5. The standard APT language is used. APT is still the designated standard for the Army.
6. Graphic terminals with their own minicomputers can be added as required. (Interfacing units to the remote computer can be achieved by contracting with any of a number of companies dealing with CAD/CAM.)
7. A remote large computer can serve reasonably up to 10 depots for part programming. It can also accept the additional load of running scientific, payroll and other services. Most depots have such a large computer. The workload is such that they are, in most cases, only utilized part time, thus they could easily accept an NC machine tool programming load without disrupting the operation. To put it differently, some depots would not have to buy a computer for the introduction of an NC machine capability. Another possibility is for the 10 depots to share in the cost of the remote centralized computer

installation. For example, a total central system costing two million dollars would cost each of the 10 depots only two hundred thousand dollars.

8. This system paves the way for data interchange since all branch depots tie into the centralized computer, and data exchange can take place with any two depots or the total.

9. This system has been proven by successful operation by the Air Force and Navy for over 10 years.

10. Having the same NC machine tools by type and manufacturer, one post processor in the central computer can serve them all. This meets the criterion for standardization.

11. The possibility of having a central parts programming facility would require one library of postprocessors, design materials, manuals, tape repository, records, plotters, etc.

Disadvantages:

1. The system is highly vulnerable. If the main computer malfunctions due to any cause, the system is made inoperative.

2. The minimum storage capacity required for the use of an APT system is rather high (250 K bytes in the core storage, supported by a disc or drum system with about 3 M bytes, and a 200-ft. magnetic tape with about 3 M bytes).

3. The main computer costs around two million dollars, not including the instruments and support equipment at each depot.

4. The complexity of APT is high when it is used to describe a simple forming problem.

5. There are a small number of technological descriptions possible.

6. For simple part programming, a person with considerable background and experience in machining may still require two to four weeks to program proficiently. The programming of complex parts requires a highly trained person with a good or excellent background in machining and an equal background in solid geometry and the easy visualization thereof. In addition, he must have had significant experience in programming in APT.

7. Editing of the program, though straightforward, lacks the interaction utility found in graphic systems. Editing is an interrupted procedure.

8. A large computer requires special accommodations, air conditioning, raised floors, special power, clean room environment, etc.

Other refined advantages and disadvantages of lesser significance can be ferreted out of the assembled information. This, however, adds little, if any more information than listed above. No attempt is made at this point to single out a preferred or possible best system. The NC Study visitation teams have now visited all of the depots in DESCOM and have effectively imparted the information herein. The depots are now applying this information in diligently pursuing their needs of intelligent hardware.

REMOTE DEVIOT NO. 2, ETC.

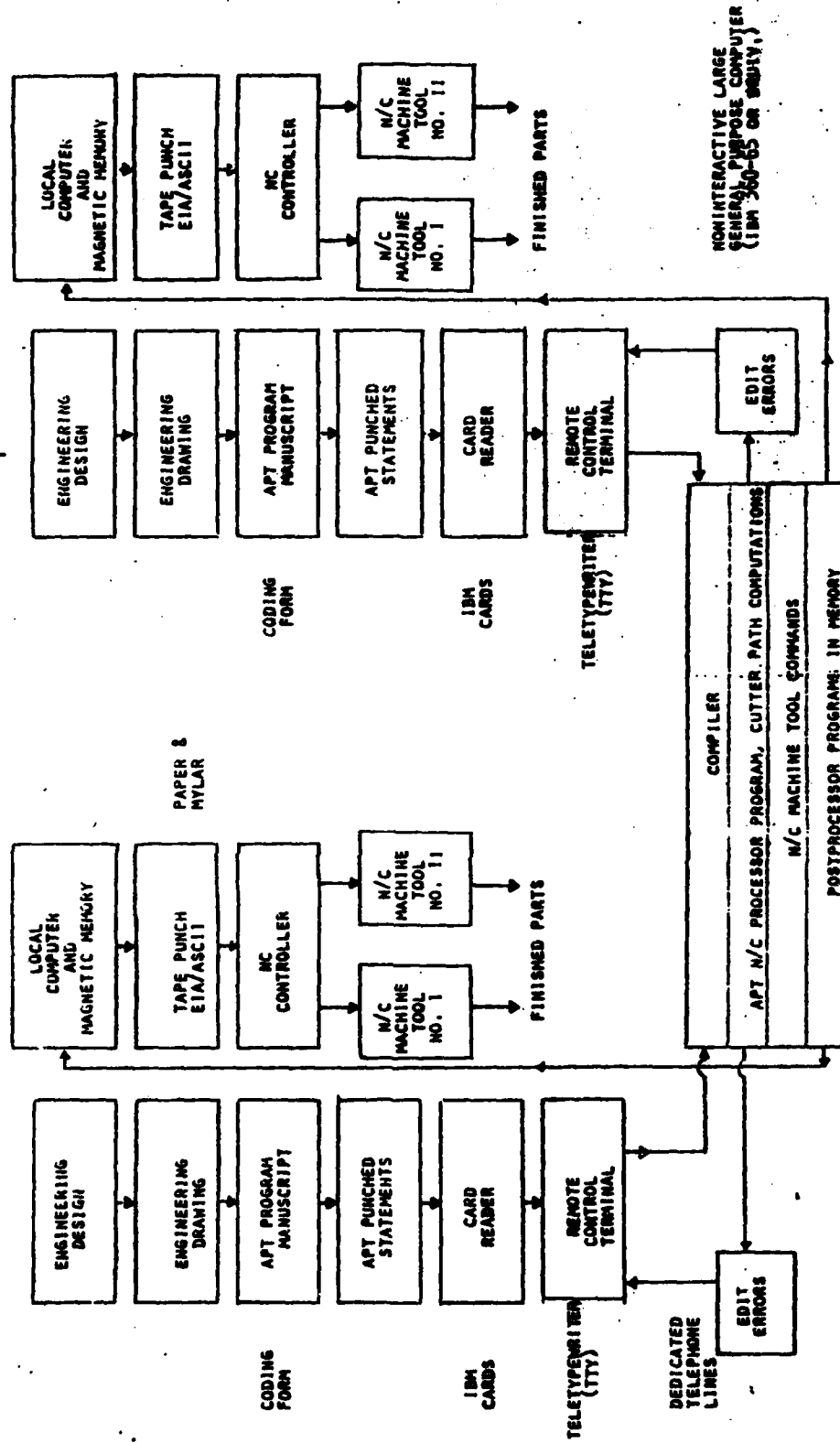


FIG. G3. DIAGRAM OF THE ELEMENTS OF SYSTEM 1 N/C MACHINE TOOL COMPLEX

DESIGN OR COMPUTER SECTION  
THE USE OF A LARGE COMPUTER OR MINICOMPUTER FOR  
SEPARATE PARTS PROGRAMMING.

SYSTEM 11

SHOP AREA

COMPUTERIZED NUMERICAL  
CONTROL (CNC) MACHINE #1

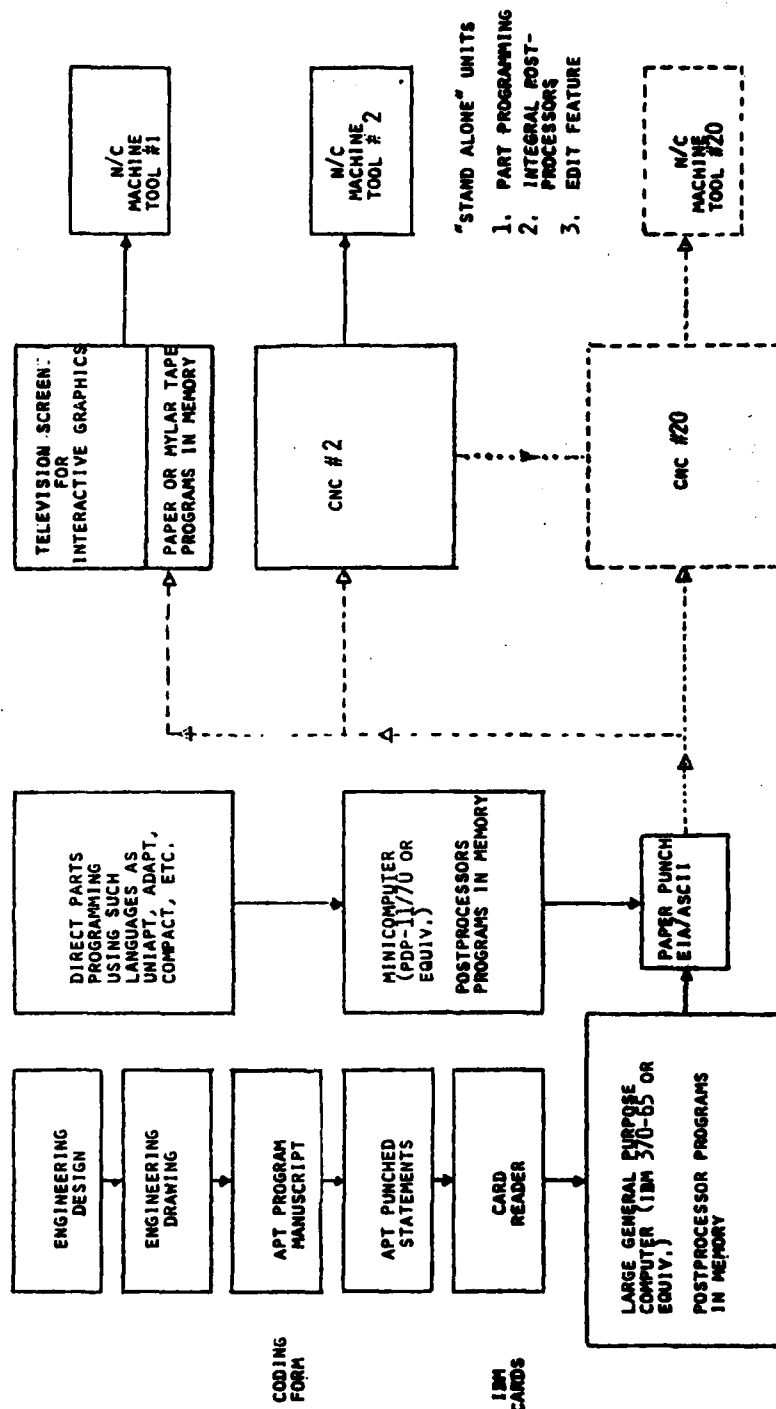


FIG. C2. DIAGRAM OF THE ELEMENTS OF SYSTEM 11. N/C MACHINE TOOL COMPLEX

# SYSTEM III

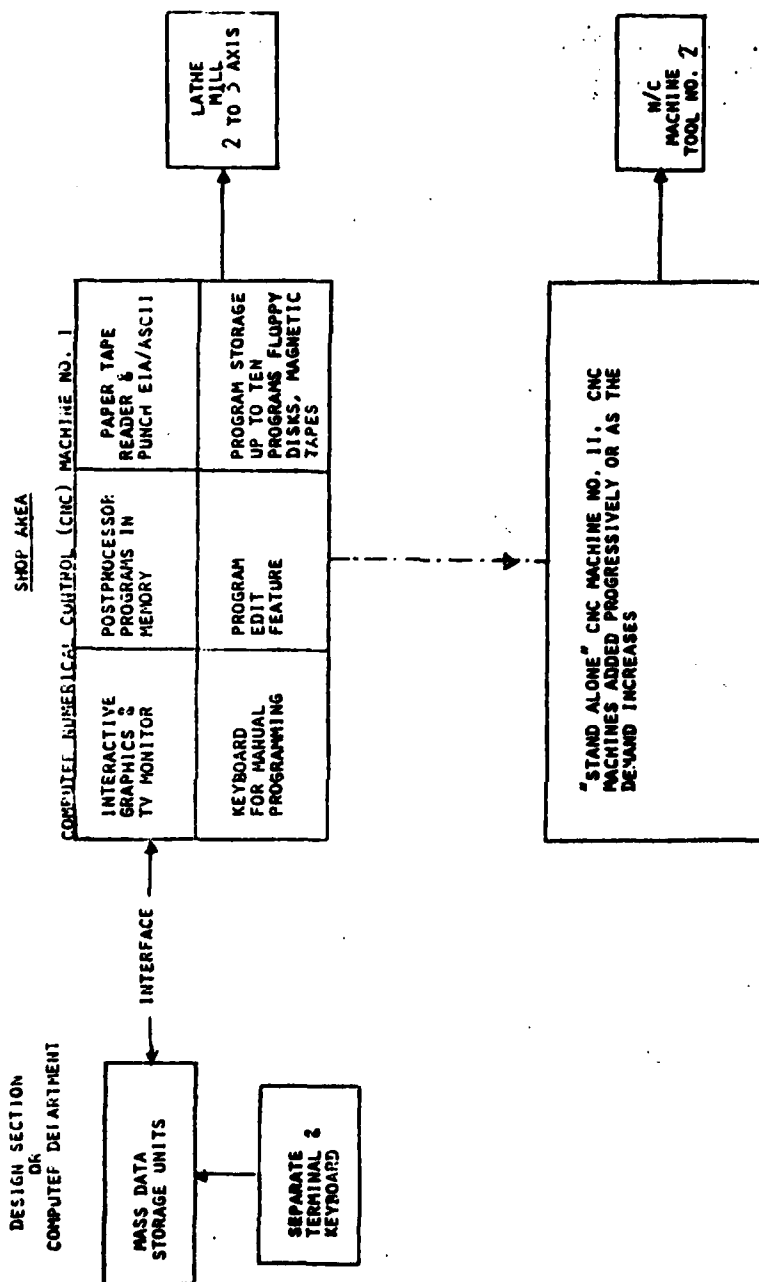
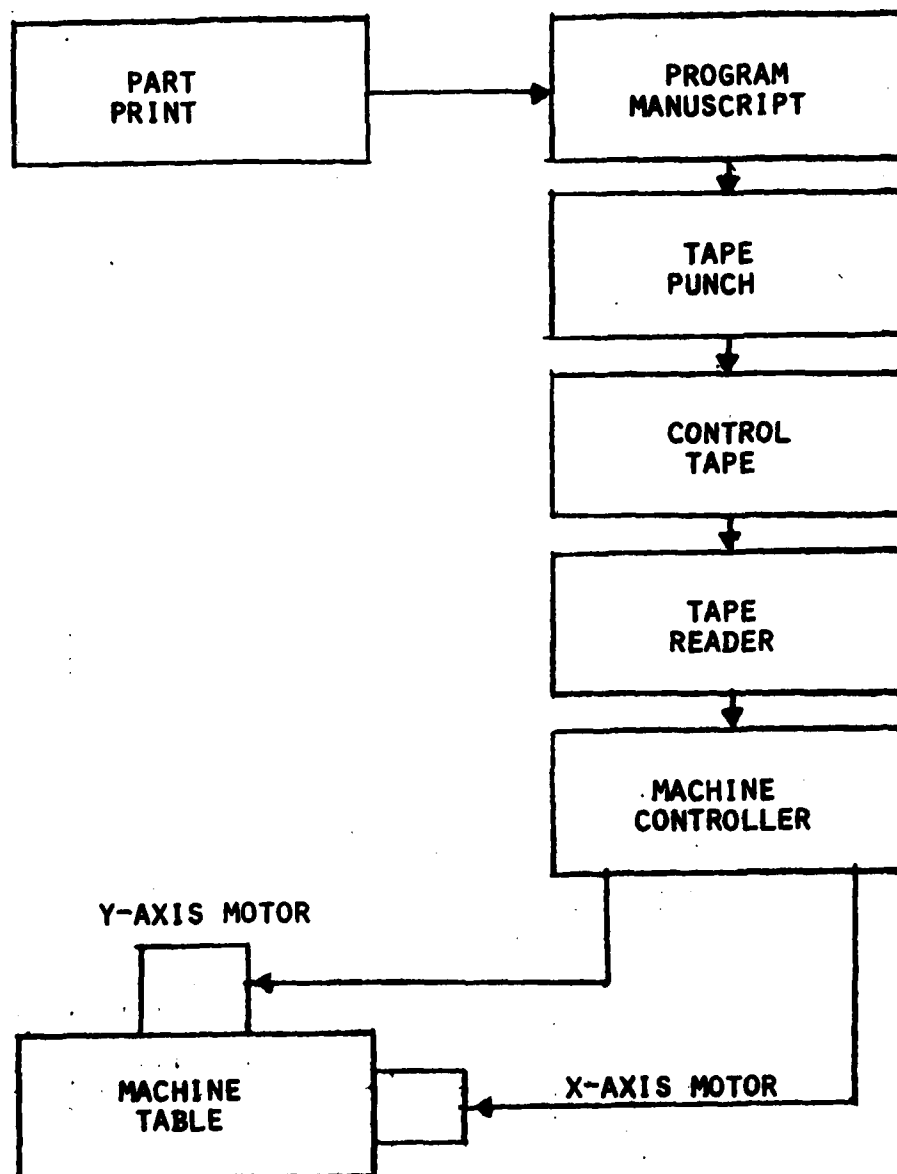


FIG. 63 DIAGRAM OF THE ELEMENTS OF SYSTEM III N/C MACHINE TOOL INSTALLATION.





**Fig. C-4. FLOW DIAGRAM FOR MANUAL PART PROGRAMMING OF A SINGLE PART FOR THE NC MACHINE.**

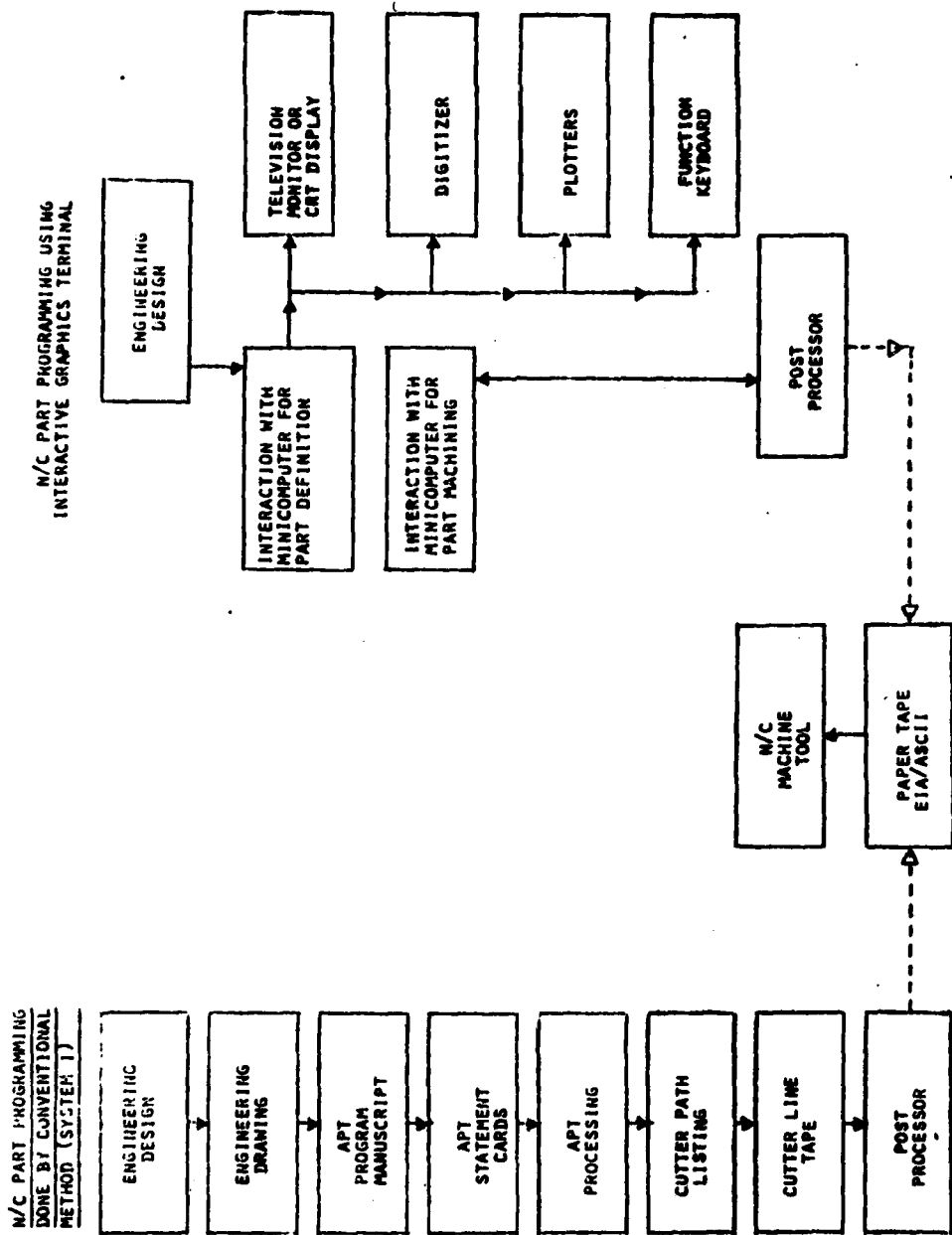


FIG. 65. COMPARISON OF CONVENTIONAL APT PART PROGRAMMING WITH AN INTERACTIVE GRAPHICS TERMINAL USING A MINICOMPUTER IN THE SYSTEM.



# STARTER SYSTEM

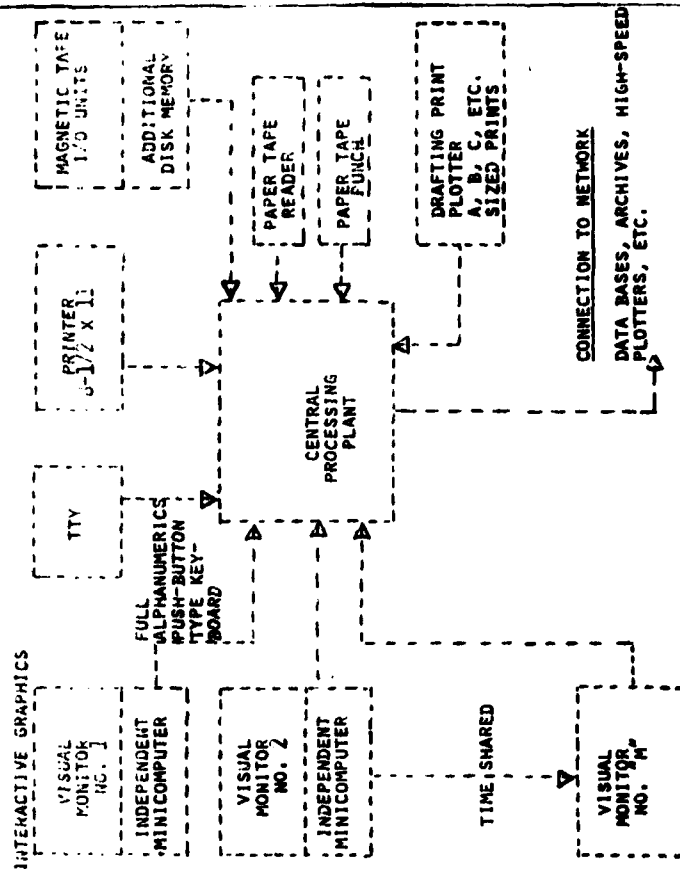
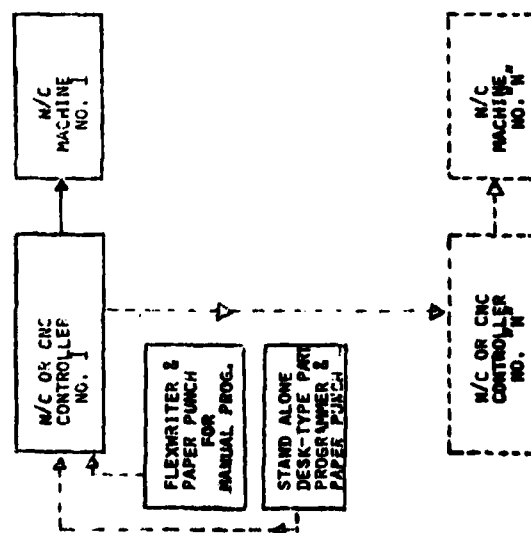
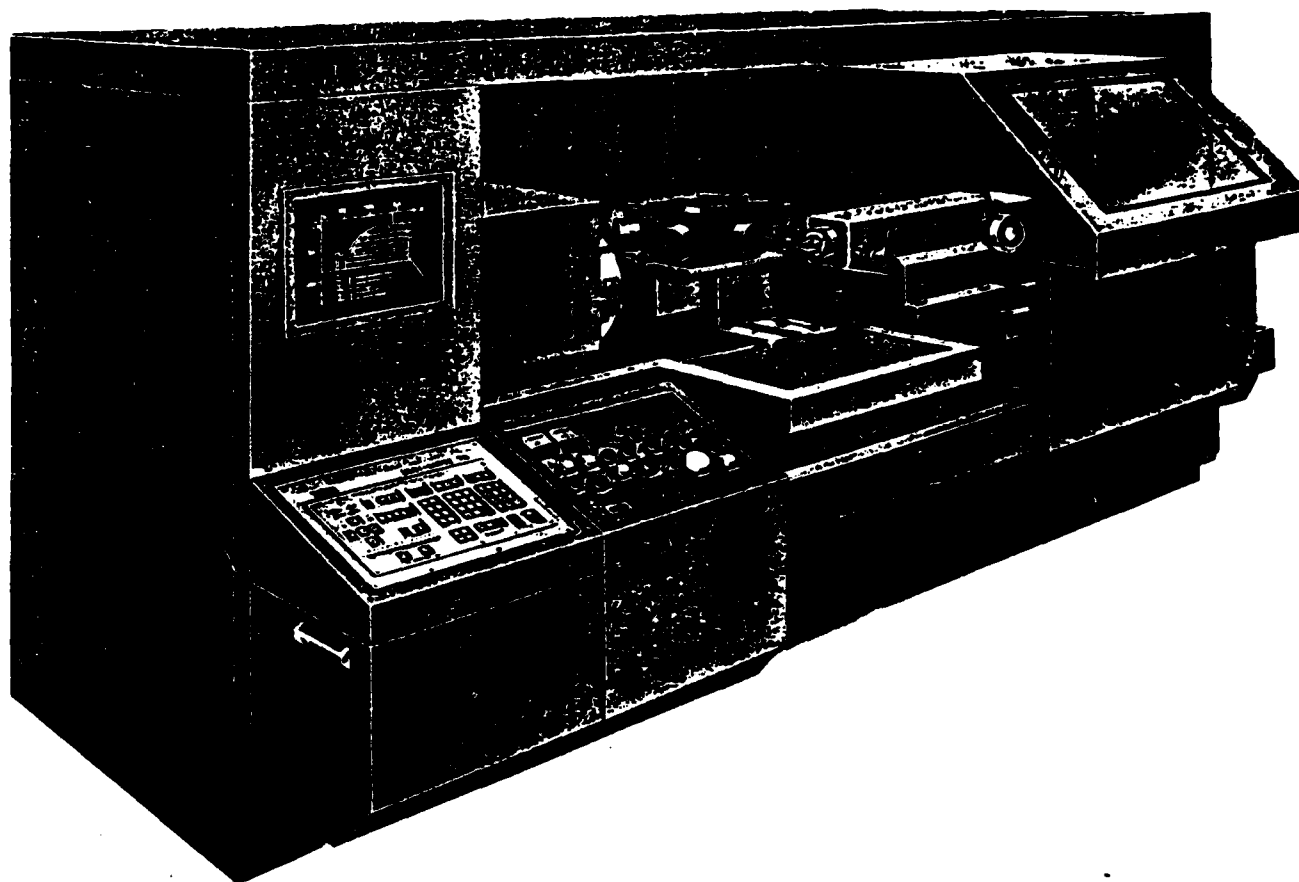


FIG. 67. N/C MACHINE TOOL SYSTEM

Fig. C-8.

## COMPARISON OF SYSTEMS I, II AND III

TOPIC	System I	System II	System III
1. Type system	N/C	N/C	CNC
2. Multi-depot system	Yes	Single	Single
3. Vulnerability	High	Low	Low
4. Meets Army readiness criteria	Yes	Yes	No
5. How many axes move simultaneously?	5	5	3
6. Point-to-Point, contouring, or both	Both	Both	Pt-to-Pt
7. Metric and English	Yes	Yes	Yes
8. Can Adaptive Control be included	Yes	Yes	Yes
9. Computer: large (IBM 360-65) or microcomputer	Large	Large/Mini	Mini
10. Computer: remote or local	Remote	Local	Local
11. Language: APT, proprietary,	APT	AOT	Prop
12. Editing interactive, manual	inter-active	inter-active	Prop
13. Processor: proprietary, public	Prop	Prop	Prop
14. Modular construction, plug-in circuit boards	Partly	Partly	Yes
15. Postprocessor: proprietary, public	Prop	Prop	Prop
16. Machine controller program storage; paper tape, magnetic tape, floppy disk and magnetic core	All	All	All
17. System cost nominal (millions of dollars)	1-2	1-2	0.2
18. Part programmer training			
a. Extensive machining experience and materials knowledge	Yes	Yes	Yes
b. Shop math, and algebra	Yes	Yes	Yes
c. Solid geometry and visualizations	Yes	Yes	No
19. Training period, 2-2½ axis	2-4 wks	2-4 wks	2 wks
20. Training period, 4-5 axis	Add 6 wks	Add 6 wks	N/A
21. Who does training; Army (ANETA), company?	Army	Both	Both



**Fig.C-9.** A CNC lathe with "show-and-tell" graphic display, automatic self-programming system, built-in postprocessor and tapeless spindle control. (General Numeric Corporation).

Appendix D

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15. FIGURE D-9: DD Form 1342, DoD Property Record (Edition of 1 August 1977)
16. FIGURE D-10: Military Specification MIL-M-80255, Machining Centers, Vertical, Single Spindle, Computer Numerical Control (CNC), dated 6 March 1978



## APPENDIX D

### PROCUREMENT

#### 1. INTRODUCTION.

The subject or title of Procurement, at least for the purpose of the study, was to categorize a number of topics which all have the same, or similar, bearing or relationship. Webster's Dictionary defines the word as: "A means of obtaining or getting by care, effort, or the use of special means." Thus, it was logical to classify such topics as; "Authorization", "Funding", "Acquisition", "Site Preparation", and "Specifications" under this title. They are all essential topics, and must be considered and applied in some form or manner, before an NC/CAM facility can become operational, or even expanded.

Within these topics, there is a wide assortment and variety of procedures and processes that are applicable, and which for the moment, must be adhered to. The following paragraphs are designed to specify and explain, in detail, the type and extent of actions which are required, and which must be complied with. Also, explanations and clarifications are provided, wherever changes have been achieved.

#### 2. AUTHORIZATION.

Authorization includes all the steps necessary to seek approval to acquire and to retain a given item for a specific intended purpose. Unfortunately, the authorization cycle consists of a number of different requirements, and documents must be processed through different channels to different agencies and headquarters. Due to organizational structuring and layering, a simplified system is not presently available. However, certain recommended changes will be submitted, in hopes of eliminating and/or reducing processing delays, and for streamlining the cycle and thereby making the system more responsive to the needs and requirements of the depots on a more timely basis.

An overview of the many authorization channels identifies the following as current systems; i.e., Depot Maintenance Plant Equipment Program (DMPE), Economic Analysis (EA), Type Classification Exemption (TCE), Line Item Number (LIN), New Start Proposals, Table of Distribution and Allowances (TDA), and Automatic Data Processing Equipment (ADPE). As indicated, time frames and the extensive details required by many of these separate channels, impact the depots and prevents the timely response to mission demands and in providing an effective materiel readiness posture. Current procedures and regulations (AR 71-6, AR 310-49, AR 18-1, AR 18-3, AR 235-5, DARCOM-R 750-2 and

others) require considerable long lead time and pre-positioning of equipment requirements. Although personnel at DESCOM (Industrial Engineering) indicate that they will coordinate with other authorization points upon receipt of a DMPE source document, there is no clear cut or simple system for processing an equipment request for authorization in a timely manner. Nor is there any coordinated system for accomplishing the requirements with a single input. As a result, the depots are plagued with considerable documentation, justification, and submission requirements, when personnel resources and capacity are in short supply. It would appear that, a reduction in processing could help to improve productivity at a reduced cost, without too much of an impact on existing personnel. Basic essential requirements could still be accomplished on the basis of one document submission, if various offices and organizations would coordinate.

A review of regulations indicates that a "New Start" proposal should be submitted and approved before a DMPE source document is submitted. Processing is a difficult, as well as a confusing procedure to follow. In accordance with AR 235-5, and DARCOM Supplement 1 to AR 235-5, it must be prepared in a special staff study format. The complexity of requirements and the degree of detailed explanation required, are not an easy task. As the regulation implies, its purpose is to determine "whether commercial and industrial type products and services required for Army use should be procured from commercial sources, provided by in-house activities, obtained from other Federal departments or agencies, or a combination of any two or more." Unfortunately, the regulation also pertains to equipment acquisition because it involves "capital investment" criteria, and particularly when the equipment is used to produce a service or product which could conceivably, be secured from a commercial source. Thus, it is mandatory that the operations and/or functions be evaluated each time an item of equipment is being considered, if the capital investment is to exceed \$25,000. In addition, there is no exemption if an item of equipment is a replacement in an existing mission, or if the equipment is to further supplement and enhance existing operations. The problems here could cause a complete termination of an existing in-house mission or function just because a new item of equipment is being considered and requested, and if the equipment increases the productive capacity of the original equipment. Consequently, every item of NC/CAM equipment would automatically fall under this criteria, because they do improve the production capability over conventional equipment.

The requirements identified in AR 235-5, and DARCOM Supplement 1 to AR 235-5 are supposedly based on Department of Defense (DOD) Directive 4100.15, and DOD Instruction 4100.33. The parent directive to all of these, is Office of Management and Budget (OMB) Circular A-76. These

requirements were changed, effective 29 March 1976, and a new OMB Circular A-76 was published and issued. Although the policies and purpose continue to rely upon the private sector for goods and services, it does recognize "that certain functions are inherently governmental in nature and must be performed by Government personnel, and relative cost must be given appropriate consideration in decisions between in-house performance and reliance on private commercial sources." In the new Circular A-76 (Figure D-1), the modernization, replacement, upgrade, or enlargement of an activity is now defined as "expansion", with a dollar threshold of \$100,000 capital investment, or an increase in annual operating costs of \$200,000, or more. This is a more reasonable and logical approach, and eliminates the preparation of the detailed "New Start" proposal criteria. Although these changes have been published, they cannot be used until they have been considered and adopted by the Congress, and defined in the narrative instruction provided with the fiscal appropriation bill. It is hoped that these changes will be effective with FY 80. In accordance with letter, Office of the Chief of Staff, Department of the Army (DACS-DMA), Subject: Recommended Change to AR 235-5, dated 9 January 1979 (Figure D-2), DOD and DA regulations will be updated within four to six months after OMB publication. When the action becomes final, and changes are implemented, depots will no longer need worry about "New Start" requirements for the majority of their needs. The exceptions, if any, will be few and far between. As a result this will reduce time delays, and assist in improving overall productivity.

The submission of a DMPE source document to DESCOM, is supposed to trigger a series of events. This includes, requests for Type Classification Exemption for commercial items listed in Appendix D, AR 310-49; Line Item Number (LIN), and assignment of National Stock Number (NSN) by US Army Equipment Authorization Review Activity (USAEARA); TDA process through the Installation and Services Agency at Rock Island; and, if the equipment meets the criteria as Test/Measurement and Diagnostic Equipment (TMDE), appropriate forms must be submitted to the DA/TMDE Office at Lexington - Blue Grass Army Depot. Also, in some cases, when computers or mini-computers are employed in certain applications, a request must be separately submitted through Management Information Systems channels in accordance with AR 18-1.

The DMPE program consists of the identification of requirements to support projected depot materiel maintenance workloads, and the subsequent planning, programming, budgeting, reviewing and approval necessary to obtain the requested items. In accordance with DARCOM Regulation 750-2, these requirements may be based on new mission assignments, increased projected workload, facilities modernization projects, equipment replacement due to age or wear, or other modernization/standardization projects. It further indicates that

advance planning of requirements is required to assure inclusion into the Five Year Modernization Plan.

Each depot establishes their DMPE program by preparing a planning outline for each DMPE requirement. The planning outlines for the five consecutive future fiscal year programs will be included in the Depot Five Year Plan. DESCOM will receive, review, validate and approve (or disapprove) the Five Year Plan. A similar DMPE Five Year Plan is prepared and submitted by the Materiel Readiness Commands (MRC) for new items/systems to be introduced into the Army inventory which require depot support.

All NC/CAM equipment requirements will be included in the DMPE program, and will be submitted on the DMPE Source Document (DARCOM Form 2156-R) (Figure D-3). In accordance with letter DRSDS-RM, subject: Funding of Numerically Controlled/Computer-Aided Manufacturing (NC/CAM) Equipment, dated 12 February 1979, and 1st Endorsement, DROCP-BP, dated 12 March 1979 (Figure D-4). NC/CAM is defined as DMPE, and not as ADPE. Headquarters DARCOM stated that "considering the nature of the work that is to be performed on the NC/CAM equipment, it is appropriate to include the equipment and funding requirements for the NC/CAM in the Five Year Plan for Depot Maintenance Modernization". This information was provided to all depots during the implementation period.

An Economic Analysis, in accordance with AR 11-28, must be prepared and submitted, with the DMPE submission. An exception would be when the benefits to be gained from the analysis are not worth the minimum level of effort required to do the analysis, or when proposed actions are specifically directed by statute, regulation, or directive. For NC/CAM equipment, there is no known instance which could eliminate the need for an Economic Analysis, or some form of cost evaluation. If the planned acquisition of an NC/CAM equipment will replace conventional or other NC/CAM equipment, prepare and submit a DD Form 1106, Industrial Plant Equipment Replacement Analysis Worksheet (Figure D-5) In accordance with the AR 700-90 and DA Pam 700-23. This is an acceptable substitute for the EA indicated above, and much simpler and easier to prepare. Current procedures require that the EA be validated by the Comptroller before submission. There is no such requirement for DD Form 1106 submissions.

An item of NC/CAM equipment is usually not type-classified. That is, it is not specifically designed with military or standardized features. Because it is a commercial item, a request for Type Classification Exemption must be secured from the US Army Equipment Authorization Review Agency. If the request is for a commercial item listed in Appendix D, AR 310-49, the request is forwarded to Department of the Army (DA) for approval. Based on current procedures, such requests are prepared as a "Letter Request" or a locally developed form, and are submitted with the

DMPE source document. DESCOM is responsible for coordinating the action at that point. Upon approval, the equipment may be acquired. The built-in problem is the fact that there is no prescribed time frame for getting this approval. Each request seems to be handled differently, and there is no method to prevent processing delays, nor is there any acceptable method for follow-up. A suggested change would be to eliminate the letter request or local forms. All of the basic and required information is contained on the DMPE source document. In essence, let this one document serve more than one purpose. Thus, it will reduce the amount of resource time preparing and assembling a variety of documents. Also, suggest that Type Classification Exemption be processed and returned within 15 working days after receipt at USARARA. The reason being is that in most cases, approval authority has been delegated to the TDA proponent (ref: AR 310-34, para 2-20). It will be their responsibility to get concurrence from the mission assignee agency. The only problem would be in getting the various people at different locations to revise their procedures, which would increase their productivity and responsiveness to the installations.

The processing for LIN, NSN, and TDA retention authority, is now accomplished after receipt of the equipment, as indicated in AR 310-49. This, however, is only true for commercial items listed in Appendix D, AR 310-49. Items of equipment appearing in Chapters 2 and 6, SB 700-20, cannot be acquired until they are included in the published (DA approved) TDA. The intent of such a requirement is understandable, but difficult to process, as much of the required information about a specific machine is not known until after it has been acquired. There doesn't seem to be any valid resolution to this problem. As a result, a series of unnecessary delays are created and adds to the excessive administrative lead times. It is unresponsive to users' needs. It would appear that an improvement in this system would be to provide better coordination and reduce the number of offices the requirement would have to be processed by. In addition, the specifying of a specific turn-around period would greatly reduce delays and improve the overall processing on a more timely basis. Is it not possible to streamline the system by placing responsibility for all actions with one organization, rather than so many independent and widely located organizations? A considerable saving in time and dollars could be realized if this is ever achieved.

### 3. FUNDING.

Funding is available from a variety of sources. This includes; Procurement Authority (PA) for Army Adopted Items; Other Procurement Authority (OPA) for Commercial Non-type Classified Items; Production Base Support funds for requirements to maintain Industrial Base (or Manufacturing Methods Technology); Research, Development, Test and Evaluation (RDTE); and Productivity Enhancing or Quick Return on

Investment Projects (QRIP). Equipment can only be funded from one type of money, never from a combination. Equipment with a Line Item Number (LIN) in SB700-20 would be procured by PA funds. All others will be funded by OPA.

Most NC/CAM equipment will be considered in the OPA category, because they are usually all commercial non-type classified. There are no standard Army Adopted items currently available. OPA funds are never actually seen at the depot level. They are controlled by a respective MRC, who will buy the equipment, which is then dispensed to a depot. There is no actual funds transferred. The depot, after securing technical approval via a DMPE source document will also receive OPA funding authorization, which will be cited on the requisition, submitted to the MRC for buy action.

The other funding sources are classified as special for particular needs and conditions. Production Base Support, as indicated in AR 37-100-79, is for "the establishment, rehabilitation, modernization, conversion, and expansion of government-owned industrial facilities to support current production and in critical areas, to expand the production base for use during mobilization." RDTE funds are restricted to actions designated as research and design, or those specifically identified and authorized by higher command.

The Productivity Enhancing Capital Investment (PECI) program includes all investment projects that will return the investment, thru manpower and/or material savings, in five years or less. As indicated in AR 5-4, there are three categories of investments for the PECI program:

(a) Major. Projects that cost over \$900,000, amortized within five years, and are for the support structure.

(b) Intermediate. Projects that cost under \$900,000, amortized within five years, and are for the support structure.

(c) Fast Payback. Projects that will pay for themselves within two years and meet specific criteria.

The Quick Return on Investment Program (QRIP), is one element of the Fast Payback category and must produce tangible savings. DA QRIP is applicable to appropriated funds, and is limited to, projects that cost \$40,000 or less; off-the-shelf commercial equipment; items not included in other requests for funds in current or prior years; and projects justified on the basis of productivity through changes of operating methods, procedures, or processes. QRIP funding for Army Industrial Fund Activities has a dollar threshold of \$100,000. Recent information provided by the Comptroller, DESCOM, indicates that the FY-80 QRIP budget

will cover NC/CAM equipment, and its threshold will be increased to \$300,000 with a three year amortization. There is a difference between AIF QRIP and Appropriated Fund QRIP. It is best to thoroughly investigate the condition before submitting a request. QRIP Project documentation must be complete and facilitate pre-investment appraisal and provide a basis for post-investment evaluation. As indicated by letter, DRCCP-SE, subject: Productivity Enhancing Capital Investment Program/Quick Return on Investment Program, dated 2 Feb 79 (Figure D-6), approved investment proposals will be submitted to DA for funding priority. First consideration will be given to investments with the fastest amortization. Following priorities will then be applied to the extent practical:

- (a) Investments that save whole manhour spaces or authorizations which can be reapplied at the local level.
- (b) Investments that avoid or reduce manhour costs or release manhours/manpower to be reapplied to other areas/use.
- (c) Investments that save consumable materials.
- (d) Investments that release manhours that cannot be reapplied to valid requirements at the local level.
- (e) Investments that produce other cost savings that can be reapplied to valid unfinanced requirements.

Further information indicates that DA approved investment proposals will be funded from either TSARCOM or ARRCOM, acting as QRIP fiscal administrator. All funds provided thru QRIP must be obligated within 90 days of release date. Additional requirements stipulate the actions to be taken by the fiscal administrator and the need for reflecting actual operational dates and changes in the investment costs and/or projected savings.

In summary, the forthcoming change in the QRIP program, makes this a more viable, and more responsive funding source for a good share of the planned NC/CAM machine tool requirements. Careful review, in advance, can be most beneficial in securing the right equipment in a timely and justified manner.

There is one other funding source, that is worthy of comment. This is the Manufacturing Methods and Technology consideration, and provides for efforts "involving the evolution of manufacturing processes, techniques, and equipment by the Government, or private industry, to provide for timely, reliable, economical, and high-quality quantity production of DoD required material; bridges the gap between prototype

production and quantity production by application of practical new production processes; and "other applications." Its application to NC/CAM is restricted to a first time process or technique, not previously done at any other installation. Recent information indicates that DESCOM depots are now able to participate in this particular program. A projected budget of 20 to 25 million dollars has been tentatively identified for FY-80 to be used by the depots.

The funding programs defined above, illustrate the need to have some media to assist the depots in identifying the types of funds and the specific guidance that is available in which to determine which funding source to pursue. Without such a "catalog" considerable research would be required to determine the proper and correct direction to follow. The benefits to be gained from such a catalog, or listing, will result in faster and more direct response to a depot's needs and requirements.

#### 4. ACQUISITION.

The acquisition cycle, although appearing to be simple, contains obstacles and restrictions that prevent timely acquisition of equipment. After the equipment has been approved and funded, much delay is experienced. An Army Adopted Item (type classified) must be requisitioned from the Item Manager at the Materiel Readiness Command (MRC). Delays are encountered if assets are not readily available for issue. The requirement is usually placed in suspense until the Item Manager has "sufficient demand" to effect a buy. Also, if the item was not listed in the published and approved TDA, the requisition was rejected. If the item is not DA controlled, or is a commercial non-type classified item, permission must be secured from the Item Manager to procure locally. Another channel to be followed requires the preparation and submission of DD Form 1419 (DOD Industrial Plant Equipment Requisition) (Figure D-7) to the Defense Industrial Plant Equipment Center (DIPEC) to determine availability, or non-availability of an identical, or similar item. If available, and acceptable, the item is issued "free" of charge. If an acceptable item is not available, or if DIPEC accepts the rejection of an offer, a Certificate of Non-Availability (CNA) is issued. This CNA is required before procurement or requisitioning can be initiated.

Within this cycle, validation of the requirement is done at various levels. The Equipment Manager at the depot, and at command level, must re-verify the need and justification for the equipment. Appropriate controls must be established to satisfy these conditions, and many cannot be accomplished until a previous action has been resolved. There is no concurrent processing allowed. As indicated in the processing for authorization, there are a number of "steps" that must be satisfied, and which must be certified with the submission of acquisition documents.



Once the initial steps are taken, a DD Form 2765-1, IAW AR 710-2, and DARCOM-R 710-4 is submitted through the Equipment Manager, to editing and cataloging. A DD Form 1419 must be prepared for all machine tools, and is submitted to DIPEC for screening. Recent information from DESCOM (reference 1st Indorsement Ltr, dated 19 Jan 79) (Figure D-8) indicates that DIPEC will screen all available DoD assets. A Certificate of Non-Availability (CNA) indicates that the Industrial Plant Equipment is not available in the DoD inventory. According to the Chief, Facilities Engineering and Management Division, DESCOM, (DRSDS-EF), upon receipt of a CNA, procurement may be initiated through the proper channels. If procurement actions has not been initiated within 90 calendar days from the date of issuance of the CNA, the request must be resubmitted back to DIPEC for a complete re-screening and for a new CNA.

After the specific item has been successfully acquired, a follow-up action must be taken to establish appropriate TDA and Property Book Accountability controls. Those items which were acquired with temporary TDA authority, on the basis of an approved DMPE request, must be documented as to the make, model, serial number, description and use. This data must be included in the next TDA update for official retention authority. In addition, a LIN is to be secured as part of the requirement.

A review of the sequences defined, indicate that there is considerable delay being experienced in the multiple channels which must currently be followed. Some reduction in time could be achieved by consolidating some actions and decisions made at the time the equipment request is approved. DESCOM personnel could coordinate directly (they imply that they are), with the Item Manager to secure a FROM (fund citation) and local purchase authority before the DMPE source document is approved. Also, more direct contact with DIPEC would help to expedite the action. Thus, no processing delays would be experienced by the depot prior to initiating local procurement action. Efforts should continue in securing a simple, straight-through system to enable depots to secure equipment needs in a more timely manner, which will make them more responsive to the Army readiness and mobilization requirements.

One further requirement that involves NC/CAM machine tools, is the requirement to report such items to DIPEC. IAW Appendix II-F, AR 700-43, a DD Form 1342 (DOD Property Record) (Figure D-9) must be completed and submitted for each new NC machine tool acquired, or those that become idle. Section VI of DD Form 1342 contains specific identifying data, from types of design in the Controller to positioning and operational requirements of the machine. It also discusses conditions of interchangeable perforated tape formats, explanation of function codes, tool change data, rotary table and pallet shuttle conditions, type of readouts, computer language used, and a variety of other topics. In

short, it provides a comprehensive identification for each NCMT in use at any location as well as those available for DIPEC screening and redistribution. Compliance with this DoD requirement is mandatory, but it will be of exceptional value to a depot in the future when evaluating the useability of an idle NCMT to perform a given function or requirement. Any acquisition from DIPEC is "free issue," and a machine requirement can be satisfied at little or no cost.

#### **5. SITE PREPARATION.**

The objective to be borne in mind in designing any foundation pad is to provide a permanent base for the NC Machine Tool (NCMT) such that movement of the base and that of the superimposed NCMT shall have the least possible movement. Machine tool builders are very aware that stability is critical to the proper performance of the NCMT, therefore, procedures and specifications unique to each machine are developed as an integral part of the purchase package. The design of a site pad should in accordance with the requirement stipulated by the Machine Tool Builder so far as possible without incurring any added expense. Often times the warranty on the machine hinges on the site pad design and construction. It is recommended that the NCMT should be physically isolated within the shop area.

One of the first decisions which must be made concerning an NC/CAM machine tool is the physical location of the unit on the shop floor. A decision must be made as to whether the NC/CAM machine should be located separately, or next to its conventional counterpart. Having made this basic decision, it is now a question of determining the exact specific location on the floor. Consideration has to be given to utility requirements (electrical, air, hydraulics, etc), proper grounding, relative location to other work areas, cleanliness, temperature, and vibrations. To obtain the desired precision, it is essential to have a good foundation for the machine NCMT. The objective of a good foundation is twofold:

- (a) Avoid vibration.
- (b) Maintain the perpendicular relationship of the machine elements.

The machine tool builder will furnish instructions and certified drawings which will serve as a guide in determining the necessary foundation. A common practice is to provide each machine tool with its own isolated pad. The pads are sometimes standardized at six (6) feet in depth. A pad is usually surrounded by cork or felt padding which acts as a buffer between the pad and the main shop floor. This isolates the machine tool foundation from other vibrations caused by equipment within the plant. Each concrete pad should be cured for a period of three

to four weeks and then sealed. After the pad has been thoroughly cured, the machine tool can then be installed. It is important to follow the vendor's instructions as close as possible.

A review of requirements indicates that each NCMT acquired should be placed on its own specified isolation pad. There is no justification for eliminating this feature. The accuracy of manufactured parts and the effective operation of a machine tool itself could be greatly affected by a poor isolation or no isolation at all. It is strongly recommended that the machine tool site be carefully and accurately prepared well in advance of the anticipated delivery.

## **6. SPECIFICATIONS.**

The complex nature of the NC/CAM machine tool requires detailed and specific information to be incorporated into the purchase specification. Federal specifications are available and should be utilized wherever possible, however, if the proper mil-spec is not available they should be used as a model format (see Figure D-10). Historically, specifications were written from information obtained from a machine tool builders sales brochure. This procedure is inadequate for NCMT. There are a number of specific functions, operations, and statements that need to be defined and specified that will enable the machine tool designer to design and build the proper NCMT as required by the facility. A specific definition of performance requirements will enable potential vendors to design equipment in the most economical way. There are 36 elements to be considered in a properly written specification. These statements are explained as follows:

(a) Basic Machining Function. This should be specific enough to allow little indecision as to what is wanted. This includes drilling, milling, turning, etc. For example, a drilling machine should not be specified when the requirements might be straight-lined milling, rough-boring, etc. Must be as specific as possible.

(b) Machining Capacity. This should list the most difficult metals and/or materials, as far as machine ability is concerned, which is expected to be run on the machine tool.

(c) Maximum Weights of Materials. A review of parts to be machined must be considered during work-mix studies and the heaviest weight identified.

(d) Maximum Size. There are two different considerations. One, the largest part identified during work-mix studies, and secondly, the potential of working two-part configurations, which could reduce loads/unload times.

(e) Machine Axes Designations and Their Characteristics. The Electronic Industries Association Standard, RS-267-A, should be specified. Axis designations, other than those shown in the standard, can be requested but it would only be adding to future problems.

(f) Standard Tape Control Function. Functions needed will be based on considerations as to the manufacturer of families of parts. Preparatory functions and other control capacities must also be clearly and carefully stated.

(g) Optional Tape Control Functions. Any function that is not essential, but would be helpful, is listed in this category. Essential functions will be stated under Standard Tape Control Functions.

(h) Positioning Drive Motors. Any special requirement or type or style of motor must be specified. Otherwise, the Machine Tool Builder will provide motors that have been determined best, based on their study, experience, testing, and user demand.

(i) Positioning Drive Actuators. The present accepted method is the ball-nut lead screw, with rack and pinion methods a far distant second. The Machine Tool Builder will recommend this method, but any other method can be specified if there is a strong conviction for it.

(j) Positioning Speeds. Positioning speeds should be listed in inches per minute or in millimeters. The positioning speeds normally refer to machine speeds when the cutting tool is out of the material.

(k) Feed Rate of Axes. This is very important as it should represent the slowest and fastest possible feed rates that can be expected in the production of parts. If it is necessary that a control accept feed rates and decimal fractions, this must be clearly stated.

(l) Axes Control Method. This is a statement of how many and which axes will be controlled by tape for simultaneous motion.

(m) Average Time to Move Axes. This entails the programmed feed rate and the distance to be moved. Careful review of this can prevent inadvertently getting involved with extremely slow movements, which could cost valuable time over a period of months.

(n) Smallest Increment of Input. This is the minimum command which can be in the tape. Parts analyses will serve as a guide as to what the smallest increment the part programmers will expect.

(o) Smallest Motion Increment. This is the smallest motion which can be physically accomplished by the machine tool. The three most common increments are 0.0001, 0.0002, or 0.0005 of an inch.

(p) Machine Position Accuracy. Linear and rotational motion positioning accuracy, and how it is to be measured must be specified. For example, this could be a representation of tolerances on hole locations, and it might be expected to place an indicator in the spindle for measuring. Accuracy statements are a problem, as they can be different, depending upon the source of the statement.

(q) Machine Position Precision. This is similar to the word "repeatability," and refers to the accuracy of how close the machine repositions itself over repeated measurements of the same characteristics.

(r) Measurement Unit. This is normally indicated in inches. However, the NCMT should be equipped with automatic metric converter.

(s) Spindles. The number of spindles, spacing, and horsepower requirements at any speed range needed must be clearly stated.

(t) Turret Spindles. A study of key parts to be machined will establish the most advantageous number of spindle positions. The number of turret positions (horizontal, vertical, slanted, etc.), the horsepower requirements, indexing time, speeds, and ranges must be specified.

(u) Spindle Feed Range. This should be specified if it is to be variable or by step motion.

(v) Method of Manual Operation. A decision must be made if this capability of override is needed.

(w) Fail Safe Features. This includes limit switches (to restrict travel), some method to stop the machine if there was a spindle overload, lubrication failure, parity fault, tape reader overshoot, data transfer faults, etc. This is one of the better advantages of CNC.

(x) Tool Changers. Automatic tool changers should be specified to include the type (drum, rack, chain, etc.), number of tools to be loaded, maximum tool diameter, tool changing time and tool coding method.

(y) Closed, Semi-Closed, or Open Loop Systems. The decision here is based on the types of machining to be accomplished and the tolerances which must be held on the parts. Open loop systems are less expensive, but are limited in the accuracy they can attain. Considerable contouring at tight tolerances would require a close loop system. Select only the least expensive unit to meet production needs.

(z) Utility Requirements. Line voltage requirements, tolerance, frequency, and power transients must be specified. Also, consideration must be made for air, hydraulics, and also for removal of chips.

(aa) Mass to be Moved. This normally is established by the builder but on rare occasions, it can be determined by the buyer if a special machine is being designed. It will be necessary to determine the mass when any retrofitting is contemplated.

The refinement of a specification, considering each of the foregoing statements, will help to weed out those machines which are not capable of performing the required functions. Each point of the specifications must be given full consideration. As indicated earlier, the use of MIL Specs can greatly assist in defining the specific machine tool needs. Federal and Military specifications and standards can be obtained without charge from the Naval Publications and Forms Center (NPFC) by telephone, telegraph, mail, or in person. All types of orders should include the customer's complete mailing address, the quantity of each document desired (maximum of 10), and the number and title of each document required. Requests should be submitted in duplicate form and be double spaced between each document number.

To submit a request by mail, write to:

Commanding Officer  
Naval Publications and Forms Center (NPFC 105)  
5801 Tabor Avenue  
Philadelphia, PA 19120

To submit a request by telephone, call Area Code (215) 697-3321.

Existing military and federal documents stocked by the NPFC are listed in the Department of Defense Index of Specifications and Standards (DODISS). The DODISS is maintained for reference at most military installations and procurement offices, and at all Small Business Administration Regional Offices, and is available by subscription, from Superintendent of Documents, Government Printing Office, Washington, DC 20402.

Subscriptions to automatically obtain one copy of every newly published standardization document, Federal and Military, in each chosen Federal Supply Class (FSC) are available from the Director, Navy Publications and Printing Service, Eastern Division, 700 Robbins Avenue, Philadelphia, PA 19111. Subscriptions must be accompanied by check or money order payable to Treasurer of the United States in the amount of \$6.00 per year for each FSC chosen. In order to list the number and title of each FSC desired, subscribers will need a Cataloging Handbook H2-1, "Federal Supply Groups and Classes," which is obtainable without charge from the Navy Publications and Printing Service, Eastern Division.



EXECUTIVE OFFICE OF THE PRESIDENT  
OFFICE OF MANAGEMENT AND BUDGET  
WASHINGTON, D.C. 20503

March 29, 1979

CIRCULAR NO. A-76

Revised

Transmittal Memorandum No. 4

TO THE HEADS OF EXECUTIVE DEPARTMENTS AND ESTABLISHMENTS

SUBJECT: Policies for Acquiring Commercial or Industrial Products and  
Services Needed by the Government

Transmitted herewith is a revision of Office of Management and Budget Circular A-76, which replaces Transmittal Memorandum No. 1, dated August 30, 1967, Transmittal Memorandum No. 2, dated October 18, 1976, and Transmittal Memorandum No. 3, dated June 13, 1977.

The revised Circular (1) reaffirms the Government's general policy of reliance on the private sector for goods and services, while recognizing that (2) certain functions are inherently governmental in nature and must be performed by Government personnel, and (3) relative cost must be given appropriate consideration in decisions between in-house performance and reliance on private commercial sources. The balanced approach in this revised Circular is designed to achieve consistent policy implementation in all agencies, equitable treatment of all parties, and improved economy and efficiency in providing goods and performing services needed by the Government.

To support the increased emphasis on relative economy of Government and contract performance, a comprehensive Cost Comparison Handbook is provided as a supplement to the Circular. This Handbook is to be used by all agencies in conducting comparative cost analyses. The Handbook provides instructions for determining the total cost to Government for each alternative and will provide a more accurate basis for cost-based decisions.

This revision of Circular A-76 is the result of an extensive review of the Circular and its implementation by executive agencies, and careful consideration of all comments submitted on the draft revision that was published in August 1978. Many of those comments were accommodated through clarification and refinement of the draft. Supplementary guidance on special subjects will be developed as needed.

Application to R&D Activities

Some concern was expressed over the potential impact of the application of this Circular to Government R&D activities. While agencies with a need for in-house R&D capability can consider a "core capability" in this area as a "governmental function," additional guidance is needed to ensure some consistency in determining and justifying the size of that core capability and applying the Circular to R&D requirements, in excess of that level of capacity.

Figure D-1

An interagency committee jointly sponsored by the Office of Federal Procurement Policy and the Office of Science and Technology Policy, has been established under the Federal Coordinating Council for Science, Engineering, and Technology, to study these issues and recommend guidelines for appropriate and uniform agency implementation. Supplemental guidance addressing R&D activities will then be developed and, after public review and comment, be issued as an amendment to the Circular. In the interim, compliance with this Circular and the periodic review of inventoried R&D activities are to be deferred for one year pending completion of the study, except for new starts and expansions, as defined in the Circular. Additional guidance will be provided on determining justified "core capability" and applying the policy to other R&D requirements to assure that essential in-house capability is maintained, and that the Government and taxpayers' interests are properly considered in contract versus in-house decisions.

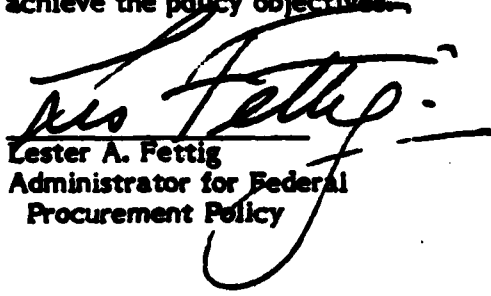
#### Government-Owned Contractor-Operated Activities

Government-owned, contractor-operated (GOCO) activities were excluded from prior issuances of the Circular. A comprehensive review of all GOCO activities is necessary to determine whether they can be completely treated under the terms of this Circular. In the interim, this Circular is to be applied only to new starts and expansions of Government-owned equipment and facilities.

#### Personnel Ceilings

The relationship between Circular A-76 and agency personnel ceilings was reviewed in some detail and clarified in the Circular. While it is clearly specified that agencies will not use the Circular to contract out solely to meet personnel ceilings, it is equally clear that agencies will contract out when justified under the Circular regardless of the relationship between personnel levels and authorized ceilings. Conversely, contracts for activities that are shown to be justified for in-house performance will be terminated as quickly as in-house capability can be established; when the additional spaces required cannot be accommodated within the agency's personnel ceiling, a request for adjustment will be submitted to OMB in conjunction with the annual budget review process.

The Office of Management and Budget will monitor agency implementation of this revised Circular, providing guidance and interpretations as required. Further revisions and supplements will be issued as necessary in the future to achieve the policy objectives.

  
Lester A. Pettig  
Administrator for Federal  
Procurement Policy

  
James T. McIntyre, Jr.  
Director





**EXECUTIVE OFFICE OF THE PRESIDENT  
OFFICE OF MANAGEMENT AND BUDGET  
WASHINGTON, D.C. 20503**

**March 29, 1979**

**CIRCULAR NO. A-76  
Revised**

**TO THE HEADS OF EXECUTIVE DEPARTMENTS AND ESTABLISHMENTS**

**SUBJECT: Policies for Acquiring Commercial or Industrial Products and  
Services Needed by the Government**

1. Purpose. This Circular establishes the policies and procedures used to determine whether needed commercial or industrial type work should be done by contract with private sources or in-house using Government facilities and personnel. This Circular replaces OMB Circular No. A-76, dated August 30, 1967, and all subsequent amendments.

2. Background. In a democratic free enterprise economic system, the Government should not compete with its citizens. The private enterprise system, characterized by individual freedom and initiative, is the primary source of national economic strength. In recognition of this principle, it has been and continues to be the general policy of the Government to rely on competitive private enterprise to supply the products and services it needs.

This policy has been expressed in Bureau of the Budget Bulletins issued in 1955, 1957, and 1960. In 1966, Circular No. A-76 was issued and, for the first time, prescribed the policy and implementing guidelines in a permanent directive. The Circular was revised in 1967, by Transmittal Memorandum No. 1, to clarify some provisions and to lessen the burden of work by the agencies in implementation. Transmittal Memorandum No. 2 was issued in 1976, providing additional guidance on cost comparisons and prescribing standard cost factors for Federal employee retirement and insurance benefits.

In 1977, a comprehensive review of the Circular and its implementation was initiated. Transmittal Memorandum No. 3 was issued on June 13, 1977, announcing the review and temporarily reducing the Government retirement cost factor. This revision is the result of that review and careful consideration of comments from all interested parties.

3. Responsibility. Each agency head has the responsibility to ensure that the provisions of this Circular are followed. This Circular provides administrative direction to heads of agencies and does not establish, and shall not be construed to create, any substantive or procedural basis for any person to challenge any agency action or inaction on the basis that such action was not in accordance with this Circular, except as specifically set forth in Section 11 below.

4. Policy. This policy builds on three equally valid policy precepts:

a. Rely on the Private Sector. The Government's business is not to be in business. Where private sources are available, they should be looked to first to provide the commercial or industrial goods and services needed by the Government to act on the public's behalf.

b. Retain Certain Governmental Functions In-House. Certain functions are inherently governmental in nature, being so intimately related to the public interest as to mandate performance by Federal employees.

c. Aim for Economy; Cost Comparisons. When private performance is feasible and no overriding factors require in-house performance, the American people deserve and expect the most economical performance and, therefore, rigorous comparison of contract costs versus in-house costs should be used, when appropriate, to decide how the work will be done.

5. Definitions. For the purposes of this Circular:

a. A "Government commercial or industrial activity" is one which is operated and managed by a Federal executive agency and which provides a product or service that could be obtained from a private source. A representative, but not comprehensive, listing of such activities is provided in Attachment A. An activity can be identified with an organization or a type of work, but must be (1) separable from other functions so as to be suitable for performance either in-house or by contract; and (2) a regularly needed activity of an operational nature, not a one-time activity of short duration associated with support of a particular project.

b. An "expansion" is the modernization, replacement, upgrade, or enlargement of a Government commercial or industrial activity involving additional capital investment of \$100,000 or more, or increasing annual operating costs by \$200,000 or more; provided, the increase exceeds 20% of the total investment or annual operating cost. A consolidation of two or more activities is not an "expansion" unless the proposed total capital investment or operating cost exceeds the total from the individual activities by the amount of the threshold. An expansion which increases either capital investment or annual operating cost by 100% or more is a "new start."

c. A "conversion" is the transfer of work from a Government commercial or industrial activity to performance by a private commercial source under contract.

d. A "new start" is a newly-established Government commercial or industrial activity, including a transfer of work from contract to in-house performance. Also included is any expansion which would increase capital investment or annual operating cost by 100% or more.

e. A "private commercial source" is a private business, university, or other non-Federal activity, located in the United States, its territories and possessions, the District of Columbia, or the Commonwealth of Puerto Rico, which provides a commercial or industrial product or service required by Government agencies.

f. A "Governmental function" is a function which must be performed in-house due to a special relationship in executing governmental responsibilities. Such governmental functions can fall into several categories:

(1) Discretionary application of Government authority, as in investigations, prosecutions and other judicial functions; in management of Government programs requiring value judgments, as in directing the national defense; management and direction of the Armed Services; conduct of foreign relations; selection of program priorities; direction of Federal employees; regulation of the use of space, oceans, navigable rivers and other natural resources; direction of intelligence and counter-intelligence operations; and regulation of industry and commerce, including food and drugs.

(2) Monetary transactions and entitlements, as in Government benefit programs; tax collection and revenue disbursements by the Government; control of the public treasury, accounts, and money supply; and the administration of public trusts.

(3) In-house core capabilities in the area of research, development, and testing, needed for technical analysis and evaluation and technology base management and maintenance. However, requirements for such services beyond the core capability which has been established and justified by the agency are not considered governmental functions.

#### 6. Scope.

a. No executive agency will engage in or contract for commercial or industrial activities except in accordance with the provisions of this Circular, or as otherwise provided by law, including, for example, Title 44 of the U.S. Code.

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b. The implementation provisions of this Circular do not apply to governmental functions as defined in paragraph 5(f). These functions must be performed in-house by Government personnel.

c. This Circular applies to the need for Government ownership in any "new start" or "expansion" of a Government-owned, contractor-operated (GOCO) facility.

d. Additional provisions are as follows:

(1) This Circular does not provide authority to enter into contracts. Guidelines governing contracts for goods and services are set forth in applicable acquisition regulations.

(2) This Circular will not be used as authority to enter into contracts which establish a situation tantamount to an employer-employee relationship between the Government and individual contract personnel. Additional guidance on this subject is provided in the Federal Personnel Manual issued by the Office of Personnel Management.

(3) This Circular will not be used to justify a conversion to contract solely to meet personnel ceilings or to avoid salary limitations. When in-house performance of a "new start" is justified under this Circular but cannot be accommodated within agency personnel ceilings, an appeal for necessary adjustment to implement this Circular agency-wide should be made to OMB in connection with the annual budget review process.

(4) Major system acquisitions are governed by the provisions of OMB Circular No. A-109, "Major System Acquisitions." Reliance on the private sector is one of the general policies contained in Circular A-109 to ensure competitive consideration of all alternatives before making a decision as to the best method of satisfying an agency mission need.

(5) This Circular does not apply to consulting services of a purely advisory nature relating to the governmental functions of agency administration and management and program management. Assistance in the management area may be provided either by Government staff organizations or from private sources, as deemed appropriate by executive agencies, in accordance with executive branch guidance on the use of consulting services.

(6) This Circular applies to printing and binding only in those agencies or departments which are exempted by law from the provisions of Title 44 of the U.S. Code.

(7) This Circular should not be applied when it would be contrary to law or inconsistent with the terms of any treaty or international agreement.

## **7. Use of Products and Services from Other Federal Agencies.**

a. Excess property and services available from other Federal agencies should be used in preference to new starts or contracts, unless the needed product or service can be obtained more economically in the private sector. This is consistent with the Federal Property and Administrative Services Act of 1949 and related regulations.

b. When a commercial or industrial activity operated by an agency primarily to meet its own needs has excess capacity, that capacity can be used to provide products or services to other agencies.

(1) If a formal program is established for managing excess capacity, such as the ADP sharing program operated by GSA, capacity that has been reported as excess can be used by other agencies with no further justification. In the absence of a formal program and report of excess capacity, another agency's use of a Government activity must be justified in accordance with paragraph 8 of this Circular. When the cost justification is used, the agency requiring the product or service will solicit competitive bids or proposals to establish commercial costs, and award a contract when more economical. The prospective providing agency will prepare the Government cost estimate, in accordance with this Circular, for comparison with the commercial cost.

(2) It is not intended that agencies create or expand capacity for the purpose of providing commercially available products or services to other agencies. When the performing agency's own requirements increase, capacity used to support other agencies is no longer excess and should be used in preference to acquisition of additional capability. Consequently, agencies should not expand a commercial or industrial activity which is providing products or services to other agencies. The user agency (or agencies) should be informed, with sufficient notice to arrange alternative sources, that the support will be terminated unless exceptional circumstances prevent that agency from finding a new source.

c. In some cases, a commercial or industrial activity is operated for the primary purpose of providing a product or service to other agencies, such as the Federal Data Processing Centers or the Office of Personnel Management training centers. All such activities must be reviewed under this Circular to determine whether continued Government operation is justified. The review should be made at the earliest possible date, but under no circumstances later than October 1, 1981. Prior to that review, agencies may use the products and services available without further justification. When continued Government operation of the activity is approved, agencies may use the products or services provided, up to the level of capability approved, with no further justification. When expansion of such an activity is proposed, the justification for approval under this Circular can be based on the entire workload, including work for other agencies.

8. Government Operation of a Commercial or Industrial Activity. Government operation of a commercial or industrial activity may be authorized under one of the following conditions.

a. No Satisfactory Commercial Source Available.

(1) A Government commercial or industrial activity can be authorized without a comparative cost analysis when it is demonstrated that:

(a) There is no private commercial source capable of providing the product or service that is needed; or

(b) Use of a private commercial source would cause an unacceptable delay or disruption of an essential agency program.

(2) Before concluding that there is no private commercial source capable of providing the needed product or service, the agency must make all reasonable efforts to identify available sources.

(a) As a minimum, the agency must place at least three notices of the requirement in the Commerce Business Daily over a 90-day period. In the case of urgent requirements, publication in the Commerce Business Daily can be reduced to two notices over a 30-day period.

(b) Agencies' efforts to find satisfactory commercial sources, especially small and minority-owned businesses, should include obtaining assistance from the General Services Administration, Small Business Administration, and the Domestic and International Business Administration in the Department of Commerce.

(3) A conclusion that use of a commercial source would not be satisfactory because it would cause an unacceptable delay or disrupt an agency program requires a specific documented explanation.

(a) Delay or disruption must be spelled out specifically in terms of cost, time and performance measures.

(b) Disruption must be shown to be of a lasting or unacceptable nature. Transitory disruption caused by conversions are not sufficient grounds.

(c) In all cases, specific explanations must be documented. If it is known that the function has been performed by contract elsewhere or at another time, the justification must specify why circumstances are substantially different.

(d) The fact that an activity involves a classified program, or is part of an agency's basic mission, or that there is a possibility of a strike by contract employees is not an adequate justification for in-house performance of that activity. Urgency by itself is not an adequate reason for starting or continuing a Government commercial or industrial activity. It must be shown that commercial sources are not able and the Government is able to provide the product or service when needed.

b. National Defense.

(1) A Government commercial or industrial activity, operated by military personnel, may be justified when:

(a) The activity or military personnel assigned are utilized in or subject to deployment in a direct combat support role;

(b) The activity is essential for training in those skills which are exclusively military in nature; or

(c) The activity is needed to provide appropriate work assignments for career progression or a rotation base for overseas assignments.

(2) A Government commercial or industrial activity providing depot or intermediate level maintenance may be justified in accordance with criteria approved by the Secretary of Defense to ensure a ready and controlled source of technical competence and resources necessary to meet military contingencies. These criteria will limit the extent of in-house capability and capacity within the military departments for depot and intermediate maintenance support of mission-essential equipment to the minimum necessary to accomplish that objective. Justification under these criteria will require a detailed explanation, on a case-by-case basis, why the needed capability cannot be supplied by:

(a) A private commercial source; or

(b) Contract operation of Government-owned facilities.

Such justification must be approved at the military department assistant secretary level or equivalent in the defense agencies.

c. Higher Cost. A Government commercial or industrial activity may be authorized if a comparative cost analysis, prepared in accordance with paragraph 9 of this Circular, indicates that the Government can provide or is providing a product or service at a lower total cost than if it were obtained from a private commercial source.

9. Cost Comparisons. A decision for in-house performance based on economy must be supported by a comparative cost analysis prepared in accordance with this Circular and the supplementing Cost Comparison Handbook.

a. Common Ground Rules.

(1) Both Government and commercial cost figures must be based on the same scope of work and the same level of performance. This requires the preparation of a sufficiently precise work statement with performance standards that can be monitored for either mode of performance.

(2) Standard cost factors will be used as prescribed by the Cost Comparison Handbook and as supplemented by agencies for particular operations. It will be incumbent on each agency to defend any variations in costing from one case to another.

(3) Cost comparisons are to be aimed at full cost, to the maximum extent practical in all cases. All significant Government costs (including allocation of overhead and indirect costs) must be considered, both for direct Government performance and for administration of a contract.

(4) In the solicitation of bids or offers from contractors for workloads that are of a continuing nature, unless otherwise inappropriate, solicitations should provide for prepriced options or renewal options for the out-years. These measures will guard against "buy-in" pricing on the part of contractors. While recompetition also guards against "buy-ins," the use of prepriced or renewal options provides certain advantages such as continuity of operation, the possibility of lower contract prices when the contractor is required to provide equipment or facilities, and reduced turbulence and disruption.

(5) Ordinarily, agencies should not incur the delay and expense of conducting cost comparison studies to justify a Government commercial or industrial activity for products or services estimated to be less than \$100,000 in annual operating costs. Activities below this threshold should be performed by contract unless in-house performance is justified in accordance with paragraph 8.a. or b. However, if there is reason to believe that inadequate competition or other factors are causing commercial prices to be unreasonable, a cost comparison study may be conducted. Reasonable efforts should first be made to obtain satisfactory prices from existing commercial sources and to develop other competitive commercial sources.

(6) The cost comparison will use a rate of 10% per annum as the opportunity cost of capital investments and of the net proceeds from the potential sale of capital assets, as prescribed in the Cost Comparison Handbook.



**b. Calculating Contract Costs.**

(1) The contract cost figure must be based on a binding firm bid or proposal, solicited in accordance with pertinent acquisition regulations. Bidders or offerors must be told that an in-house cost estimate is being developed and that a contract may or may not result, depending on the comparative cost of the alternatives.

(2) The factor to be used for the Government's cost of administering contracts, in addition to other costs of using contract performance as specified in the Handbook, is 4% of the contract price or expected cost.

**c. Calculating Costs of Government Operation.**

(1) Each agency should assure that Government operations are organized and staffed for the most efficient performance. To the extent practicable and in accordance with agency manpower and personnel regulations, agencies should precede reviews under this Circular with internal management reviews and reorganizations for accomplishing the work more efficiently, when feasible.

(2) The Government cost factor to be used for Federal employee retirement benefits, based on a dynamic normal cost projection for the Civil Service Retirement Fund, is 20.4%.

(3) The Government cost factor to be used for Federal employee insurance (life and health) benefits, based on actual cost, is 3.7%.

(4) The Government cost factor to be used for Federal employee workmen's compensation, bonuses and awards, and unemployment programs is 1.9%.

**d.** An existing in-house activity will not be converted to contract performance on the basis of economy unless it will result in savings of at least 10% of the estimated Government personnel costs for the period of the comparative analysis.

**e.** A "new start" will not be approved on the basis of economy unless it will result in savings compared to contract performance at least equal to 10% of Government personnel costs, plus 25% of the cost of ownership of equipment and facilities, for the period of the comparative analysis.

**f.** All cost comparisons must be reviewed by an activity independent of the cost analysis preparation to ensure conformance to the instructions in the Cost Comparison Handbook.

## **10. Administering the Policy.**

### **a. Implementation.**

(1) Each agency will designate an official at the assistant secretary or equivalent level, and officials at subordinate contact points for major components, to have overall responsibility for implementation of this Circular within the agency.

(2) Each agency will establish one or more offices as central points of contact to maintain cognizance of specific implementation actions. These offices will have access to all decision documents and data pertinent to actions taken under the Circular and will respond, in a timely manner, to all requests concerning inventories, schedules, reviews, and results of reviews. In considering requests which include information supplied by contractors or prospective contractors, agencies will be guided by OFPP Policy Letter No. 78-3, "Requests for Disclosure of Contractor-Supplied Information Obtained in the Course of a Procurement."

(3) Within 90 days after the date of issuance, each agency will promulgate this Circular, with the minimum necessary internal instructions, identifying the designated official and the central and subordinate contact points. When issued, copies of the internal instructions will be forwarded to OMB's Office of Federal Procurement Policy for review. Copies of subsequent changes will also be forwarded for review.

(4) Each agency will recognize that work for the Federal Government may be performed by use of military personnel, civilian employees, and contract services, and that past experience demonstrates that all three methods have been responsive and dependable in performing sensitive and important work.

(5) Each agency will ensure that contracts awarded as a result of reviews under Circular A-76:

(a) Contain all applicable clauses and provisions related to equal employment opportunities, veterans' preference, and minimum wages and fringe benefits, including implementation of OFPP Policy Letter No. 78-2, dated March 29, 1978, relating to "wage busting;"

(b) Include a provision, consistent with Government post employment conflict of interest standards, that the contractor will give Federal employees, displaced as a result of the conversion to contract performance, the right of first refusal for employment openings on the contract in positions for which they are qualified;

(c) Are awarded to a responsible and responsive bidder or offeror, as required by applicable acquisition regulations; and

(d) Are administered and monitored to achieve proper performance, using appropriate contractual remedies any time performance is less than satisfactory.

(6) Each agency will exert maximum effort to find suitable employment for any displaced Federal employees, including:

(a) Giving them priority consideration for suitable positions with the Government;

(b) Paying reasonable costs for training and relocation when these will contribute directly to placement;

(c) Arranging for gradual transition when conversions are made to provide greater opportunity for attrition and placement; and

(d) Coordinating with the Department of Labor and other agencies to obtain private sector employment for separated workers.

(7) Each agency will provide for alterations to the mode of performance to be timed in consonance with, and adjusted for, the budget process to the extent required and consistent with the firm bid cost study approach.

b. Inventories. Each agency, will immediately compile a complete inventory of all commercial and industrial activities subject to this Circular.

(1) Agencies will prepare and maintain a complete inventory of all individual commercial or industrial activities (as defined in paragraph 5.a.), which they operate. In addition to general descriptive information, the inventory should include for each activity: the amount of the Government's capital investment, the annual cost of operation, the date the activity was last reviewed, and the basis on which the activity is being continued under this Circular. The inventory will be updated at least annually to reflect the results of reviews as conducted.

(2) Agencies will also prepare and maintain an inventory of all contracts in excess of \$100,000 annually, except those awarded under a duly authorized set aside program, for services which the agency determines could reasonably be performed in-house, including any activities that have been converted from in-house to contract performance. In addition to general descriptive information, the inventory will include: the contract number, name of the contractor, contract period, period of any options, and the total contract price or estimated cost. Inventory updates will reflect exercise of options and the termination and award of contracts.

c. Reviews. Agencies will prepare a detailed schedule for the review of each commercial or industrial activity and contract in the inventory to determine if the existing performance, in-house or contract, continues to be in accordance with the policy and guidelines of this Circular. The flow chart provided as Attachment B demonstrates the sequence of actions required for proper implementation of the Circular.

(1) The schedule for review of in-house commercial and industrial activities will provide for review of all activities during the three-year period following issuance of this revised Circular. Consideration should be given first to criteria that do not concern cost. Unless continuation is justified under paragraphs 8.a. or b., a cost comparison must be conducted to determine the relative cost of Government and private performance.

(2) The schedule for review of contracts will show the date that each contract (including options) will expire, and the date that the requirement will be reviewed to determine if contract performance is to be continued. The agency will review the contract cost and determine whether it is likely that the work can be performed in-house at a cost that is less than contract performance by 10% of Government personnel costs plus 25% of the cost of ownership of equipment and facilities. When this is determined to be likely, a cost comparison will be conducted.

(3) Both schedules will be completed and provided to the Office of Federal Procurement Policy, OMB, within 120 days of the date of issuance of this Circular. These schedules will be made available by the agency to all potentially affected employees and their representatives, and published for the information of contractors.

(4) Reviews will be conducted in accordance with the schedules, unless it is determined that a change in the schedule will be in the best interest of the Government. In such cases, after approval by the agency head or his designee, the schedule can be revised with 60 days notice to all affected parties.

(5) After the initial review, activities approved for continuation will be reviewed again at least once every five years. When it is determined by the agency head or his designee that the circumstances which supported the initial approval are not subject to change, subsequent reviews may be waived. These activities will be retained in the inventory, however, and so identified. A copy of the justification and the waiver will be made available to all interested parties upon request to the agency contact point.

(7) When the number of commercial and industrial activities and the number of covered contracts is so great that reviews cannot be completed in the prescribed time period, the agency may request approval from the Office of Federal Procurement Policy, OMB, to schedule the reviews over a longer period.

d. New Starts.

(1) A new start should not be initiated by an executive agency unless the justification for establishing the activity under the provisions of this Circular has been reviewed and approved by a senior official of the agency. A new start which involves a capital investment or annual costs of \$500,000 or more must be approved by the agency head or by an official at the assistant secretary or equivalent level.

(2) The actions to be taken under this Circular should normally be completed before the agency's budget request is submitted to OMB. Data in support of such budget requests will be submitted in accordance with OMB Circular No. A-11. In the case of a proposed new start involving a major capital investment where the item to be acquired requires a long lead time (e.g., ADP system, building), approval of budget resources will not constitute OMB approval of that method of meeting the agency need. A final determination to initiate the new start or to rely on a private commercial source, within the resources approved, will be made in accordance with this Circular and other applicable policies, prior to any commitment to a particular acquisition strategy.

(3) When Government ownership of facilities is necessary, the possibility of contract operation must be considered before in-house performance is approved as a new start. If justification for Government operation is dependent on relative cost, the comparative cost analysis may be delayed to accommodate the lead time necessary for acquiring the facilities.

(4) When in-house performance to meet a new requirement is not feasible, or when contract performance would be under an authorized set-aside program, a contract can be awarded without conducting a comparative cost analysis.

e. Set-Aside Programs

(1) It is the general policy of the Government, as expressed in the Small Business Act, to ensure that small businesses, including those owned and managed by disadvantaged persons, receive a fair share of Government contract awards.

(2) Consequently, contracts awarded under authorized set-aside programs will not be reviewed for possible in-house performance. Additionally, new requirements which would be suitable for award under a set-aside program should be satisfied by such a contract without a comparative cost analysis.

(3) On the other hand, in-house activities (in excess of \$100,000 annually) will not be considered for performance under a set-aside contract except when the conversion is justified by a comparative cost analysis.

## 11. Appeals.

a. Each agency will establish a procedure for an informal administrative review of determinations made under this Circular. This procedure will only be used to resolve questions of the determination between contract and in-house performance, and will not apply to questions concerning award to one contractor in preference to another contractor. Upon written request from a directly affected party raising a specific objection, the appeals procedure will provide for:

(1) An independent, objective review of the initial determination and the rationale upon which the decision was based.

(2) An expeditious determination, within 30 days, made by an official at the same or higher level than the official who approved the original decision.

b. The appeals procedure is to provide an administrative safeguard to assure that agency decisions are fair, equitable, and in accordance with established policy. This procedure does not authorize an appeal outside the agency or a judicial review.

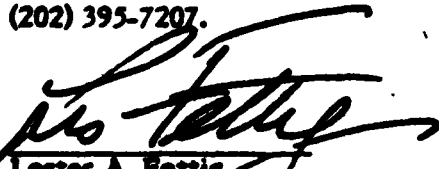
c. Since the appeal procedure is intended to protect the rights of all affected parties -- Federal employees and their representative organizations, contractors and potential contractors, and contract employees and their representatives -- the procedure and agency determinations may not be subject to negotiation, arbitration, or agreements with any one of those parties. Agency decisions are final.

d. Agency appeal procedures, when issued, will be submitted to OFPP for review pursuant to paragraph 10.a.(3).

## 12. Effective Date.

This Circular is effective May 1, 1979, but need not be applied to studies in process where a solicitation for contract bids or proposals was issued prior to the effective date.

Questions or inquiries about this Circular or its implementation should be addressed to the Office of Federal Procurement Policy, OMB, telephone number (202) 395-7207.

  
Lester A. Fetting  
Administrator for Federal  
Procurement Policy

  
James T. McIntyre, Jr.  
Director

## **ATTACHMENT A**

### **EXAMPLES OF COMMERCIAL AND INDUSTRIAL ACTIVITIES**

#### **Audiovisual Products and Services**

Photography (still, movie, aerial, etc.)  
Photographic processing (developing, printing, enlarging, etc.)  
Film and videotape production (script writing, direction, animation, editing, acting, etc.)  
Microfilming and other microforms  
Art and graphics services  
Distribution of audiovisual materials  
Reproduction and duplication of audiovisual products

#### **Automatic Data Processing**

ADP services — batch processing, time-sharing, etc.  
Programming and systems analysis, design, development, and simulation  
Key punching and data entry services  
Systems engineering and installation  
Equipment installation, operation, and maintenance

#### **Maintenance, Overhaul, and Repair**

Aircraft and aircraft components  
Ships, boats, and components  
Motor vehicles  
Combat vehicles  
Railway systems  
Electronic equipment and systems  
Weapons and weapon systems  
Medical and dental equipment  
Office furniture and equipment  
Industrial plant equipment  
Photographic equipment  
Space systems

#### **Systems Engineering, Installation, Operation, and Maintenance**

Communications systems — voice, message, data; radio, wire, microwave, and satellite  
Missile ranges  
Satellite tracking and data acquisition  
Radar detection and tracking  
Television systems — studio and transmission equipment, distribution systems, receivers, antennas, etc.  
Recreational areas  
Bulk storage facilities

**Manufacturing, Fabrication, Processing, and Packaging**

Ordnance equipment  
Clothing and fabric products  
Liquid, gaseous, and chemical products  
Logging and lumber products  
Communications and electronics equipment  
Rubber and plastic products  
Optical and related products  
Sheet metal and foundry products  
Machined products  
Construction materials  
Test and instrumentation equipment

**Real Property**

Design, engineering, construction, modification, repair, and maintenance of buildings and structures  
Construction, alteration, repair, and maintenance of roads and other surfaced areas  
Landscaping, drainage, mowing and care of grounds

**Industrial Shops and Services**

Machine, carpentry, electrical and other shops  
Industrial gas production and rectifying  
Equipment and instrument fabrication, repair and calibration  
Plumbing, heating, electrical, and air conditioning services, including repair  
Fire protection and prevention services  
Custodial and janitorial services  
Refuse collection and processing

**Health Services**

Surgical, medical, dental, and psychiatric care  
Hospitalization, outpatient, and nursing care  
Physical examinations  
Eye and hearing examinations -- manufacturing and fitting glasses and hearing aids  
Medical and dental laboratories  
Dispensaries  
Preventive medicine  
Dietary services  
Veterinary services



**Transportation**

Operation of motor pools  
Bus service  
Vehicle operation  
Air transportation  
Water transportation  
Trucking and hauling

**Printing and Reproduction**

Printing and binding -- where the agency or  
department is exempted from the provisions  
of Title 44 of the U.S. Code  
Reproduction, copying, and duplication  
Blue-printing

**Research and Development**

Basic research  
Applied research  
Development  
Concept formulation and demonstration  
R&D studies  
R&D testing  
R&D support services

**Office Services**

Stenographic recording and transcribing  
Word processing/data entry  
Mail/messenger  
Translation  
Information systems and distribution  
Financial auditing and services  
Management auditing

**Security**

Guard and protective services  
Systems engineering, installation, and maintenance of security systems  
and individual privacy systems  
Forensic laboratories

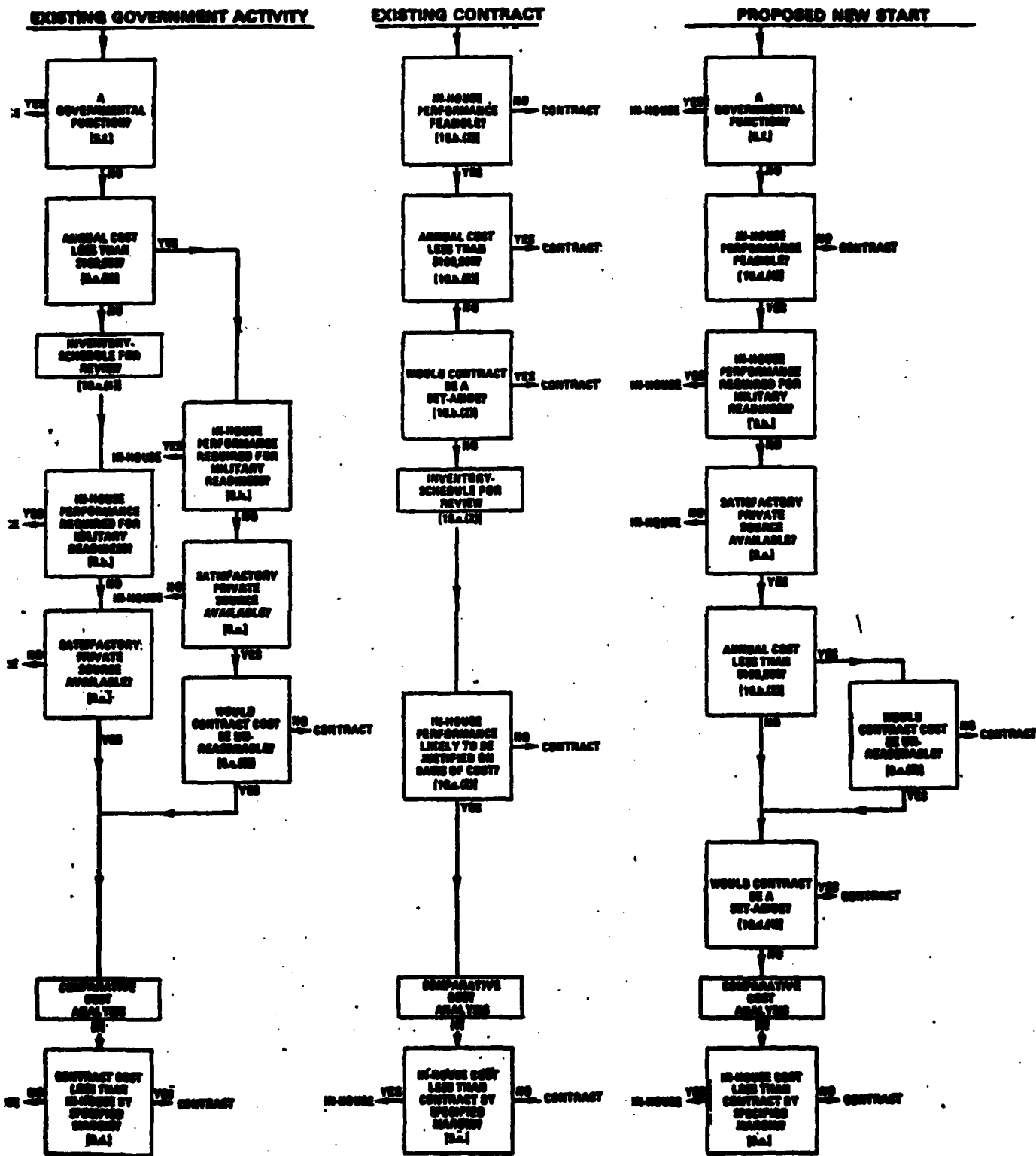
### Food Services

Operation of cafeterias, mess halls, kitchens, bakeries, dairies,  
and commissaries  
Vending machines  
Ice and water

### Other Services

Laundry and dry cleaning  
Library operation  
Mapping and charting  
Architect and engineer services  
Geological surveys  
Cataloging  
Training -- academic, technical, vocational, and specialized (within the  
limitations of P.L. 85-507, unless waived by the Office of Personnel  
Management)  
Operation of utility systems (power, gas, water, steam, and sewage)

# IMPLEMENTATION OF OMB CIRCULAR A-76



Reference to baseline is to appropriate paragraph in Circular A-76



**DEPARTMENT OF THE ARMY**  
**OFFICE OF THE CHIEF OF STAFF**  
**WASHINGTON, D.C. 20310**

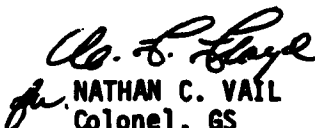
**9 JAN 1979**

**DACS-DMA**

**SUBJECT: Recommended Change to AR 235-5.**

**Commander  
Sacramento Army Depot  
ATTN: SDSSA-C  
Sacramento, CA. 95813**

- 1. Reference is made to your DA Form 2028, Recommended Change to Publications and Blank Forms, dated 21 December 1978, requesting change to AR 235-5.**
- 2. The OMB suggested changes to OMB Circular A-76 attached to referenced recommendation have not been finalized and published. Until that time, the corresponding DOD and Army regulations, including AR 235-5, cannot be changed. Estimated date of publication of OMB Circular A-76 is February 1979. DOD and Army regulations should be updated within four to six months after OMB publication.**

  
**NATHAN C. VAIL**  
**Colonel, GS**  
**Chief, Army Management Division**  
**Management Directorate**

**Figure D-2**

<b>DMPE SOURCE DOCUMENT</b> <b>(AMCC 750-3)</b>						<b>1. SOURCE DOCUMENT NO.:</b>				
<b>2. TYPE SUBMISSION:</b> <input type="checkbox"/> EMERGENCY <input type="checkbox"/> CHANGE <input type="checkbox"/> NORMAL				<b>3. SUBMISSION DATE:</b>		<b>4. PRON:</b>				
<b>5. QUANTITY:</b>		<b>6. RECEIVING ACTV:</b>		<b>7. REQUIRED DATE:</b>		<b>8. ITEM MANAGER:</b>		<b>9. PRIORITY:</b>		
<b>10. PSC/PSN:</b>		<b>11. NOMENCLATURE:</b>				<b>12. LHM:</b>				
<b>13. DMPE COST:</b>		<b>14. INSTALLATION COST:</b>		<b>15. TOTAL COST:</b>		<b>16. FUNDING:</b> <input type="checkbox"/> OMA <input type="checkbox"/> PEMA <input type="checkbox"/> OTHER _____				
<b>17. TDA:</b>		<b>18. AUTHORIZED:</b>		<b>19. ON HAND:</b>		<b>20. REQUIRED:</b>		<b>21. TYPE:</b> <input type="checkbox"/> MC <input type="checkbox"/> TMDE		
<b>22. REQUIREMENT FOR:</b> <div style="display: flex; justify-content: space-between;"> <div style="width: 48%;">           a. <input type="checkbox"/> NEW MISSION ASSIGNMENT            b. <input type="checkbox"/> INCREASED PROJECTED WORKLOAD            c. <input type="checkbox"/> FACILITY MODERNIZATION PROJECT         </div> <div style="width: 48%;">           d. <input type="checkbox"/> DMPE AGE/WEAR REPLACEMENT            e. <input type="checkbox"/> AMORTIZED COST SAVINGS            f. <input type="checkbox"/> OTHER         </div> </div>										
<b>23a. CMB:</b>		<b>b. M.C.:</b>	<b>c. WES:</b>	<b>d. PRON:</b>		<b>e. QTY:</b>	<b>f. SIC/SM:</b>		<b>g. NOMENCLATURE:</b>	
<b>24. NARRATIVE:</b>										
<b>25. POINT OF CONTACT</b>										
<b>a. BDPOT:</b>					<b>b. COMMAND:</b>					
<b>26. APPROVAL</b>										
<b>a. TRNG:</b>					<b>b. TECHNICAL:</b>					
_____ DATE                      SIGNATURE					_____ DATE                      SIGNATURE					

DRCCP-BP (12 Feb 79) 1st Ind

SUBJECT: Funding of Numerically Controlled/Computer-Aided Manufacturing  
(NC/CAM) Equipment

HQ, US Army Materiel Development and Readiness Command, 5001 Eisenhower Avenue,  
Alexandria, VA 22333

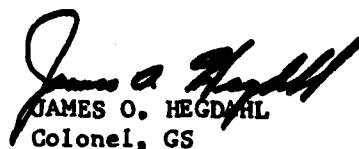
12 MAR 1979

TO: Commander, US Army Depot System Command, ATTN: DRSDS-RM, Chambersburg,  
PA 17201

1. Reference is made to letter, DRCCP-SE, 2 Feb 79, subject: Productivity Enhancing Capital Investment Program/Quick Return on Investment Program (copy inclosed).
2. Based on informal conversations with HQ DARCOM and HQ DESCOM personnel, and considering the nature of the work that is to be performed on the NC/CAM equipment, it is appropriate to include the equipment and funding requirements for the NC/CAM in the 5 year plan for Depot Maintenance Modernization.
3. QRIP investment projects must produce tangible savings, be within legal and regulatory constraints on capital investments, and be limited to the criteria contained in reference 1.

FOR THE COMMANDER:

1 Incl  
as

  
JAMES O. HEGDAHL  
Colonel, GS

Chief, Resources and Programs Division

Figure D-4



DEPARTMENT OF THE ARMY  
US ARMY DEPOT SYSTEM COMMAND  
CHAMBERSBURG, PENNSYLVANIA 17201

IN REPLY REFER TO  
ORDS. RM

12 FEB 1979

SUBJECT: Funding of Numerically Controlled/Computer-Aided  
Manufacturing (NC/CAM) Equipment

Commander  
US Army Materiel Development and Readiness Command  
ATTN: DRCPP-R  
5001 Eisenhower Avenue  
Alexandria, VA 22333

1. A HQDESCOM team is studying NC/CAM and its applications to the Depot System. The problem of financing potential requirements is a part of the study. During informal conversations between HQDESCOM and HQDARCOM, an interpretation problem evolved. NC/CAM Equipment is automatic data processing equipment (ADPE), according to HQDARCOM, Directorate for Management Information Systems (Maurice Johnson), while NC/CAM Equipment is Depot Maintenance Plant Equipment according to HQDARCOM, Office of Manufacturing Technology (Fred Michel).

2. The interpretation that Directorate for Management Information Systems personnel relate to is the definition of computer in Part V of the DARCOM FY1979/80 Command Operating Budget which is: "The term computer includes any device capable of accepting and storing data or elements of information, executing a systematic sequence of logic operations on that data or information through a stored program (software or firmware), and producing control or information outputs." The following definitions are provided by HQDESCOM Equipment Managers to explain the subject equipment:

a. NC - A numerically controlled (NC) system is machinery controlled automatically by coded instructions. The NC system consists of two basic elements: (1) the machine that does the work, and (2) an electronic control unit which directs the machine's operations. A few machines operate directly from computers or by magnetic tape, but most get instructions by punched tape.

b. CAM - Computer-aided manufacturing (CAM) is manufacturing processes or machines that are controlled by computers. CAM can also be workloading, scheduling, and storage systems controlled by computers.

12 199 17

DRSDS-RM

SUBJECT: Funding of Numerically Controlled/Computer-Aided  
Manufacturing (NC/CAM) Equipment

3. Two problems evolve from the different interpretations of what NC/CAM is. First, which five year plan, ADP or Depot Maintenance Modernization, should include the equipment and budgetary requirements for NC/CAM. Secondly, NC/CAM is productivity enhancing capital equipment and may qualify for funding under the Quick Return on Investment Program (QRIP). QRIP items may be financed with procurement funds or the Army Industrial Fund/Fast Payback System (AIF/FPS), however, the AIF/FPS cannot finance ADPE. Request you assist us in determining the proper method/s to use to budget for and finance NC/CAM equipment.

FOR THE COMMANDER:

  
U. X. VASNERINI  
Comptroller



MACHINE TOOL REPLACEMENT ANALYSIS WORK SHEET				ANALYSIS NUMBER		Form Approved Budget Bureau No. 22-8179	
				DATE			
1. ACTIVITY		2. LOCATION		3. SHOP		4. BUILDING NO.	
5. PRESENT EQUIPMENT				6. PROPOSED EQUIPMENT			
a. DESCRIPTION				a. DESCRIPTION			
b. MANUFACTURER		c. MODEL NO.		b. MANUFACTURER		c. MODEL NO.	
d. PRODUCTION EQUIPMENT CODE				d. PRODUCTION EQUIPMENT CODE			
e. DEPARTMENTAL IDENTIFICATION NO.		f. YEAR BUILT	g. TOTAL ACQUISITION COST	h. QUANTITY	i. QUANTITY	j. PRODUCTIVITY INCREASE RATIO	
7. OPERATING COST ANALYSIS FOR EQUIVALENT OUTPUT (Next Year)							
FACTOR				a. PRESENT EQUIPMENT		b. PROPOSED EQUIPMENT	
a. MACHINE LOAD (Hours next year)							
b. DIRECT LABOR				\$		\$	
c. INDIRECT LABOR				\$		\$	
d. FRINGE BENEFITS				\$		\$	
e. MAINTENANCE				\$		\$	
f. POWER				\$		\$	
g. SCRAP/REWORK				\$		\$	
h. TOOLING				\$		\$	
i. SAVINGS/OTHER OPERATIONS, ASSEMBLY				\$		\$	
j. OTHER COSTS				\$		\$	
k. TOTAL OPERATING COSTS				\$		\$	
l. NET OPERATING COSTS FAVORING PROPOSED EQUIPMENT (k, col a, minus k, col b) \$							
8. CAPITAL COST ANALYSIS OF PROPOSED EQUIPMENT (Next Year)							
a. ACQUISITION COST				\$			
b. INSTALLATION, TRANSPORTATION AND MISCELLANEOUS COSTS				\$			
c. TOTAL INSTALLED COSTS (8a plus 8b)				\$			
d. PRESENT DISPOSAL VALUE OF PRESENT EQUIPMENT				\$			
e. NET REQUIRED INVESTMENT (8c minus 8d)				\$			
f. SERVICE LIFE				Years			
g. CHART PERCENT				%			
h. TOTAL CAPITAL COST (8e X 8g)				\$			
i. NEXT YEARS SAVINGS FROM REPLACEMENT (7j minus 8h)				\$			

DD FORM 1106  
1 AUG 57

Figure D-5

GPO 507322



*Cy for BIP.*

DEPARTMENT OF THE ARMY  
HEADQUARTERS US ARMY MATERIEL DEVELOPMENT AND READINESS COMMAND  
5001 EISENHOWER AVENUE, ALEXANDRIA, VA. 22304

DRCCP-SE

2 FEB 1979

SUBJECT: Productivity Enhancing Capital Investment Program/  
Quick Return on Investment Program

SEE DISTRIBUTION

1. References:

- a. AR 5-4, DA Productivity Improvement Program, 18 Aug 76.
- b. AR 11-28, Economic Analysis and Program Evaluation for Resource Management, 2 Dec 75.
- c. DARCOM-R 5-8, DARCOM Productivity Improvement Program, 17 March 1978.
- d. DARCOM-R 5-10, Quick Return on Investment Program (QRIP), 22 May 1978.
- e. Message, DRCCP-BF, 081700Z Dec 78, subject: DARCOM FY 81-85 Program Development.

2. The DOD Capital Investment Program has been revised and expanded. Pending publication of revision to ref 1a, the following is a description of the DOD Capital Investment Program and interim guidance for DARCOM conduct of the DA Quick Return on Investment Program.

- a. The program is titled the DOD Productivity Enhancing Capital Investment (PECI) Program. Peci will include all investment projects that will return the investment, through manpower and/or materiel savings, in five years or less.

Figure D-6

*1. 2. 3. 4. 5. 6. 7. 8. 9. 10.*

DRCCP-SE

SUBJECT: Productivity Enhancing Capital Investment Program/  
Quick Return on Investment Program

b. There are three categories for investments within the PEGI Program:

(1) Major - projects that cost over \$900 thousand, amortize within five years, and are for the support structure.

(2) Intermediate - projects that cost under \$900 thousand, amortize within five years, and are for the support structure.

Categories (1) and (2) will be collectively monitored but will remain within traditional appropriations. DARCOM is currently, through programming and budget channels, identifying PEGI dollars for the FY 81-85 Program (ref 1e).

(3) Fast Payback (current DA QRIP) - projects that will pay for themselves within two years and meet specific criteria given below. QRIP projects will be funded at DA level using appropriated Productivity Enhancing Incentive (PEI) funds.

3. DOD Fast Payback (hereafter referred to by the DA program title, QRIP):

a. DA FY 79 appropriated funding level for QRIP is \$5.9 million (\$4.9 million OPA, \$1.0 million PAA (AMMO)).

b. QRIP investment projects must produce tangible savings, be within legal and regulatory constraints on capital investments, and be limited to the criteria at Inclosure 1.

4. The Congressional imposed limit of \$40,000/project (para 1a of inclosure) and the OSD imposed lease/buy restriction (para 2b of inclosure) will be reclaimed, with the latter scheduled for review at the end of the second quarter. Addressees are requested to submit any such projects to this headquarters in order to support the DA reclaim to OSD. In the meantime, any available alternative funding should be considered pending resolution of these issues.

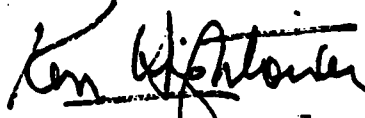
DRCCP-SE

SUBJECT: Productivity Enhancing Capital Investment Program/  
Quick Return on Investment Program

5. The impact of the PEGI Programs will be felt throughout all functional areas; this information, therefore, should be provided to all levels of management. POC's are: PEGI - Mr. Jerry Gibson, QRIP - Ms. Nita Jones, DRCCP-SE, AUTOVON 284-9483.

FOR THE COMMANDER:

1 Incl  
as

  
THOMAS K. HIGHTOWER  
LTC, GS  
Executive Officer

DISTRIBUTION:  
B

Quick Return on Investment Program  
(QRIP) Interim Guidance

1. QRIP investment projects are limited to:

a. Projects that cost \$40,000 or less. This is a Congressionally imposed ceiling and is not waivable. Caution must be exercised when proposing investments that are close to the dollar threshold. It is stressed that the \$40 thousand limit per project is firm and, therefore, cost increases cannot be honored if the resulting investment cost would exceed that limit.

b. Off-the-shelf commercial equipment, i.e., equipment that is readily available through government or commercial sources with minimal modification or that can be fabricated through combination or modification of existing equipment without extensive R&D effort.

c. Items not included in other requests for funds in current or prior years.

d. Projects justified on the basis of productivity through changes in operating methods, procedures or processes.

2. QRIP PEI funds will not be used for:

a. Projects justified solely on the basis of energy conservation benefits. However, energy savings as a by-product of a valid QRIP investment should be documented and reported.

b. Projects to purchase equipment currently being operated under lease arrangements. However, projects that would replace a piece of leased equipment with a new item that would produce a substantial change to operating methods, processes, or procedures, will be eligible as a QRIP investment.

3. QRIP project documentation must be complete and facilitate pre-investment appraisal and provide a basis for post-investment evaluation. DA Form 4477-R, Quick Return on Investment Program Project Report, will continue to be used and will be accompanied by an economic analysis as directed by ref 1a of basic letter.

Incl 1

a. DA Form 4477-R. All items on the DA Form 4477-R must be completed IAW instructions on the form, emphasizing and/or adding the following data:

(1) Item 3, From: Cdr DARCOM, ATTN: DRCCP-SE, 5001 Eisenhower Avenue, Alexandria, VA 22333.

(2) Item 11, LIN/NSN - Note requirement on reverse of Form 4477-R to comment on TC status.

(3) Item 14 - A brief description of the complete project is vital. This must include what equipment will be purchased, how it will be used, and how productivity will be increased.

(4) Items 15 and 16, Estimated reduced dollar and personnel expenses - Quantified projected benefits on an annual as well as project life basis. This latter should be noted in Item 14 pending revision to DA Form 4477-R. Additionally for Item 16, distinguish between manpower space authorizations and manpower equivalents.

(5) Items 17a and b, Program Element/Functional Element - Enter AMS PE Code from AR 37-100-FY and pertinent functional area code from Fig 2-1, AR 5-4 or a clear text description for functions/areas not listed.

(6) Item 18 - Brief description of savings disposition or how they will be reapplied.

(7) Item 19.

(a) Project Officer - Individual who is most knowledgeable about the project and who can answer specific questions regarding the proposal. Item 19a should be initialled by the local QRIP coordinator.

(b) Approving Officer - Leave blank.

b. Economic Analysis. Include projected economic life of the investment (note that "Economic Life" is defined in AR 11-28 (ref 1b of basic letter) and is different than physical or project life).

c. Review and Validation. Prior to final investment approval, the complete project package must be reviewed and validated by an impartial, independent organization other than the submitting activity - i.e., management office, cost analysis staff, etc. This review must include adequacy of EA,

verification of cost and workload data, and compliance with regulatory requirements. The concurrence of the reviewer must be attached as an inclosure to the project package.

d. An original and two copies of the complete package should be submitted to this headquarters, ATTN: DRCCP-SE, for review and submission to DA for consideration for funding. Proposals submitted with incomplete or inadequate documentation will be returned to the submitting organization.

e. Approved investment proposals will be submitted to DA for funding priority. First consideration will be given to investments with fastest amortization. The following priorities will then be applied to the extent practical:

(1) Investments that save whole manpower spaces or authorizations which can be reapplied at the local level.

(2) Investments that avoid or reduce overtime manpower costs or release man-hours/manpower, to be reapplied to other areas/use.

(3) Investments that save consumable materials.

(4) Investments that release manpower that cannot be reapplied to valid requirements at the local level.

(5) Investments that produce other cost savings that can be reapplied to valid unfinanced requirements.

4. DA approved investment proposals will be funded from either TSARCOM or ARRCOM, acting as QRIP fiscal administrators. All funds provided through QRIP must be obligated within 90 days of release date. Funds not so obligated will be withdrawn by the fiscal administrator. Requests for extensions of up to 60 days will be considered. All such requests must be submitted to this headquarters (ATTN: DRCCP-SE). Upon acquisition/installation of the equipment, a revised 4477-R will be submitted showing actual operational date and any changes to the investment cost and/or projected savings.

5. Post Audit of Investments. FY 79 Congressional guidance requires a summary of project audit results be provided annually to the Congress. Although instructions have not yet been developed, complete documentation should be developed and maintained at all phases of the investment project, from initial development of the proposal through operation of the equipment to full amortization.

<b>DOD INDUSTRIAL PLANT EQUIPMENT REQUISITION</b>				REQUISITION NUMBER		FORM APPROVED BUDGET BUREAU NO. 22-20233	
<b>SECTION I - ITEM DESCRIPTION</b>							
1. COMMODITY CODE		2. MANUFACTURER				2a. MODEL NUMBER	
3. STOCK NUMBER		4. POWER CODE		5. ESTIMATED COST		6. PHYSICAL INSPECTION REQUIRED <input type="checkbox"/> YES <input type="checkbox"/> NO	
						7. PROCUREMENT SPECIFICATION ATTACHED <input type="checkbox"/> YES <input type="checkbox"/> NO	
8. DESCRIPTION							
CONTINUED UNDER REMARKS SECTION <input type="checkbox"/> YES <input type="checkbox"/> NO							
<b>SECTION II - REQUIRING AGENCY/FACILITY/CONTRACTOR</b>							
9. NAME AND ADDRESS (Include ZIP Code)				10. CONTRACT NUMBER		10a. DATE	
						11. COMMAND CODE	
				12. PROGRAM <input type="checkbox"/> MILITARY <input type="checkbox"/> CONTRACTOR			
13. INTENDED USE				14. DATE ITEM REQUIRED AT DESTINATION		15. DATE CERT. N/A REQUIRED	
						16. PRIORITY	
17. BASIS FOR AUTHORIZATION ("X" applicable box) <input type="checkbox"/> PRODUCTION <input type="checkbox"/> MOBILIZATION <input type="checkbox"/> REPLACEMENT				18. PROCUREMENT PLANNED <input type="checkbox"/> YES <input type="checkbox"/> NO If "YES", cite Appropriation:			19. REBUILD/OVERHAUL CANDIDATE <input type="checkbox"/> YES
20. TYPED NAME AND TITLE OF REQUESTING OFFICIAL				21. SIGNATURE OF REQUESTING OFFICIAL			22. DATE
23. CERTIFICATION OF NEED BY ADMINISTERING ACTIVITY:				24. ADMINISTERING OFFICE CODE			
25. NAME AND ADDRESS (Include ZIP Code)				26. TYPED NAME AND SIGNATURE OF PRODUCTION REPRESENTATIVE			27. DATE
				28. SIGNATURE OF ADMIN. CONTRACTING OFFICER			29. DATE
<b>SECTION III - APPROVAL AUTHORITY</b>							
30. NAME AND ADDRESS (Include ZIP Code)				31. TITLE, SYMBOL AND TELEPHONE NO. OF APPROVING OFFICIAL			
				32. TYPED NAME & SIGNATURE OF APPROVING OFFICIAL			33. DATE
<b>SECTION IV - ALLOCATION AND AUTHORITY TO INSPECT (TO BE COMPLETED BY DIPEC)</b>							
34. COMMODITY CODE		35. I.D./GOVERNMENT TAG NUMBER			36. DESCRIPTION (See attached copy of DD Form 1342, dated:		
37. PRESENT LOCATION (Name, address and ZIP Code)				38. SHIPPED TO			
39. ESTIMATED TIME REQUIRED FOR SHIPMENT FROM DATE OF ACCEPTANCE (Enter number of days)							
40. AS IS CONDITION		41. TEST REQUIRED		42. REPAIR REQUIRED		43. REPAIR/OVERHAUL REQUIRED	
						44. STANDARD ATTACHMENTS REQUIRED	
45. TYPED NAME AND SIGNATURE OF ALLOCATING OFFICIAL				46. DATE		47. DATE OFFER EXPIRES	
<b>SECTION V - NON-AVAILABILITY CERTIFICATE (TO BE COMPLETED BY DIPEC)</b>							
48. The item described in Section I of this form has been screened by DIPEC against the idle inventory of the Department of Defense and it is hereby certified as not available or cannot be delivered on or before the date specified in Section II (item 14). Procurement action resulting from this Certification of Non-Availability must be initiated within 45 calendar days of the date included in this Section (item 40) or complete rescreening is required. Equipment offered by DIPEC in Section IV must be considered if the supplier cannot deliver new equipment before expiration of the period specified in Section IV (item 33).							
49. TYPED NAME AND SIGNATURE OF CERTIFYING OFFICIAL				50. DATE CERTIFICATE ISSUED		51. DATE CERTIFICATE EXPIRES	
						52. CERTIFICATE NUMBER	



**SECTION VI - CERTIFICATION OF ACCEPTANCE**

42. THE ITEM ALLOCATED IN SECTION IV OF THIS FORM

- ☐ HAS BEEN PHYSICALLY INSPECTED AND IS ACCEPTABLE. ☐ IS ACCEPTABLE WITHOUT PHYSICAL INSPECTION
- ITEM IS ACCEPTED UNDER ONE OF THESE CONDITIONS: a. ☐ AS IS CONDITION b. ☐ REPAIR REQUIRED
- c. ☐ TEST REQUIRED d. ☐ REBUILD/OVERHAUL REQUIRED e. ☐ OTHER
- ☐ IS NOT ACCEPTABLE (A complete description of conditions making item unacceptable must be stated under REMARKS below)

43. TYPED NAME AND TITLE OF CERTIFYING OFFICIAL

44. SIGNATURE OF CERTIFYING OFFICIAL

45. DATE

**SECTION VII - SPECIAL SHIPPING INSTRUCTIONS**

46. SHIP TO (Include ZIP Code):

47. FOR TRANSHIPMENT TO:

48. MARK FOR:

49. APPROPRIATION CHARGEABLE FOR

a. PACKING/CRATING/  
HANDLING

b. TRANSPORTATION

c. OTHER

d. PAYING OFFICE/ACTIVITY NAME AND  
ADDRESS (Include ZIP Code)

50. SPECIAL DISTRIBUTION OF SHIPPING DOCUMENTS AND OTHER INSTRUCTIONS

**SECTION VIII - REMARKS**

51. REMARKS

Doyle/244

DRSDS-EF (3 Jan 79) 1st Ind  
SUBJECT: Industrial Plant Equipment Supply Procedures

Mr. Doyle/pb/242-7531

19 JAN 1979

US Army Depot System Command, Chambersburg, PA 17201

TO: Commander, Sacramento Army Depot, ATTN: SDSSA-TDP, Sacramento,  
CA 95813

1. References:

a. AR 37-100-79, dated 1 May 78, subject: Appropriations and Funds Available for Obligation, Expense, and Expenditures.

b. AR 700-43, dated Nov 73, subject: Management of Defense-Owned Industrial Plant Equipment w/change 3.

2. The following information is provided on your questions:

a. What is the difference between PEMA production-based funds and PEMA?

(1) Procurement Appropriation (PA) has replaced PEMA funds, and is broken into the five separate appropriations shown below:

Aircraft Procurement, Army  
Missile Procurement, Army  
Procurement of Weapons and Tracked Combat Vehicles, Army  
Procurement of Ammunition, Army  
Other Procurement, Army (OPA)

(2) Production Base Support Funds are under the OPA appropriation and are listed in reference 1a as code (5390). Reference 1a provides a description of each appropriation/code and their use.

b. What is the required criteria for testing the supply system after a Certificate of Non-Availability is issued by DIPEC?

Per reference 1b, DIPEC will screen requisitions against all available DOD assets reported to them. A Certificate of Non-Availability (CNA) indicates the non-availability of that industrial plant equipment in the DOD inventory. Upon receipt of CNA, procurement may be initiated through the proper channels. If procurement action has not been initiated within 90 calendar days from the date of issuance of the CNA, you must go back to DIPEC for a complete rescreening and a new CNA.

Figure D-8

DRSDS-EF (3 Jan 79) 1st Ind  
SUBJECT: Industrial Plant Equipment Supply Procedures

19 JAN 1979

3. Your Comptroller can assist you in the determination of the correct funding.

FOR THE COMMANDER:

1 Incl  
nc

*P. F. Topper*  
P. F. TOPPER  
A/Chief, Fac Engr & Mgt Div

*Edwards*  
WFS 51247

SECRET-Top

3 January 1978

SUBJECT: Industrial Plant Equipment Supply Procedures

FROM: Commander  
US Army Depot Systems Command  
Charlottesville, VA 22901

TO: Commandant  
US Army Material Development  
and Readiness Command  
ASDC, SMDP-I  
Alexandria, VA 22333

1. Reference: Letter, SMDP-SUP-7, subject: Industrial Plant Equipment, dtd 14 September 1978.
2. Reference above requested assistance and clarification on the following:
  - a. What is the difference between FMA production-based funds and FMA Supply?
  - b. What is the required criteria for testing the supply system after a Certificate of Unavailability is issued by DIPEC?
  3. Considering the dollar value normally associated with industrial plant equipment, request a reply to the above reference, (See Incl 1).

FOR THE COMMANDER:

1 Incl  
cc

ROGER M. BURGESS  
LTC, GSCC  
Director for Supply

*RF*  
*my m*

SDSSA-TDP-7

14 September 1978

SUBJECT: Industrial Plant Equipment

THRU: Commander  
US Army Depot System Command  
Chambersburg, Pennsylvania 17201.

TO: Commander  
US Army Materiel Development and  
Readiness Command  
ATTN: DRCPP-I  
Alexandria, Virginia 22333

1. References:

a. Study of Certificate of Nonavailability, Screening Violations by US Army Industrial Base Engineering Activity, Rock Island, Illinois, 61299, dated 24 March 1978.

b. AR 700-43, November 1973.

2. This Command presently requisitions Industrial Plant Equipment (IPE) from the Defense Industrial Plant Equipment Center (DIPEC) at Memphis, Tennessee, without first testing the Army Inventory Control Points for asset availability. This is seemingly the procedure required by AR 700-43 which indicates DIPEC conducts a screening of all services idle and general issue assets for redistribution.

3. When assets are not available for redistribution, DIPEC issues a Certificate of Nonavailability for initiation of procurement. Reference 1a above requires a determination as to which of the following funding criteria apply:

a.. If the item is PENA production-based funded, the item is authorized for local procurement.

1401207. Procurement Policy

**SDSSA-TDP-7**

**14 September 1978**

**SUBJECT: Industrial Plant Equipment**

**b. If the item is PEMA-funded but not production-based funded, the item is ordered from the NICP.**

**c. If the item is not PEMA-funded and is available in the supply system, local procurement is not authorized. The item is ordered from the NICP.**

**d. If the item is not PEMA-funded and is not available in the supply system, local procurement is authorized,**

**4. Request clarification and/or assistance in the following:**

**a. What is the difference between PEMA production-based funds and PEMA funds?**

**b. What is the required criteria for testing the supply system after a Certificate of Nonavailability is issued by DIPEC?**

**FOR THE COMMANDER:**

**ROGER M. BENNETT  
LTC, OrdC  
Director for Supply**

PERSON CALLED	OFFICE	PHONE NUMBER AND EXTENSION
Mrs. Anderson	DIPEC, Policy & Systems	866-9279
PERSON CALLED	ADDRESS	PHONE NUMBER AND EXTENSION
MSG Ellars	DPD	839-3166

SUMMARY OF CONVERSATION

Queried Mrs. Anderson the following.

Does DIPEC screen Army ICP stocks for availability prior to issue of CNA?

Answer: Yes, all Army assets are subject to screening and when available applied against requisitions. She stated that sometimes assets will be on-hand but are not released and as such when a CNA is issued we should not be concerned with asset visibility.. Receipt of CIA is authority to buy on the local market with out going to the ICP.

*Ronald Ellars*  
RONALD ELLARS  
MSG

DA FORM 751  
APR 64

REPLACES EDITION OF 1 FEB 58 WHICH WILL BE USED.

GPO: 1965 O - 343-775-54

<b>DGD PROPERTY RECORD</b>		1. <input type="checkbox"/> ACTIVE <input type="checkbox"/> INITIAL <input type="checkbox"/> IDLE <input type="checkbox"/> CHANGE		2. JULIAN DATE	3. I.D./GOVERNMENT TAG NO.	Form Approved Budget Bureau No. 22-K0209					
		<b>SECTION I - INVENTORY RECORD</b>									
4. COMMODITY CODE	5. STOCK NUMBER	6. ACQUISITION COST	7. TYPE CODE	8. YR OF MFG	9. POWER CODE	10. STATUS CODE	11. SVC CODE	12. COMMAND CODE	13. ADM OFFICE CODE		
14. NAME OF MANUFACTURER				15. MFR'S CODE	16. MANUFACTURER'S MODEL NO.		17. MANUFACTURER'S SERIAL NO.				
18. LENGTH	19. WIDTH	20. HEIGHT	21. WEIGHT	22. CERTIFICATE OF NON-AVAILABILITY NUMBER		23. ASOD NO.	24. ARD	25. CONTRACT NUMBER			
26. DESCRIPTION AND CAPACITY											
CONTINUED ON REVERSE SIDE <input type="checkbox"/> YES <input type="checkbox"/> NO											
<b>SECTION II - ELECTRICAL CHARACTERISTICS</b>											
QUANTITY	HORSEPOWER	VOLTS	PHASE	CYCLE	AC	DC	SPEED	TYPE AND FRAME NUMBER			
28. PRESENT LOCATION						28a. DIPEC CONTROL NO.					
						29. POSSESSOR CODE					
<b>SECTION II - INSPECTION RECORD</b>											
				YES	NO				YES	NO	
30. CAN ITEM BE STORED AND MAINTAINED ON SITE FOR AT LEAST 12 MONTHS?						42. MUST ITEM BE REPAIRED/REBUILT/OVERHAULED TO PERFORM ALL FUNCTIONS?					
31. HAS ITEM BEEN REBUILT/OVERHAULED? DATE IF SO, WHEN?						43. DO GC RECORDS INDICATE SATISFACTORY PERFORMANCE? IF NO, EXPLAIN UNDER REMARKS BELOW.					
32. HAS ITEM BEEN MODIFIED FROM ORIGINAL CONFIGURATION? IF SO, EXPLAIN UNDER REMARKS BELOW.						44. ARE MANUALLY OPERATED MECHANISMS IN WORKING ORDER? IF NO, DESCRIBE UNDER REMARKS BELOW.					
33. WAS ITEM INSPECTED UNDER POWER? IF NOT EXPLAIN UNDER REMARKS BELOW.						45. ARE SCALES, DIALS, AND GAUGES WORKING AND READABLE? IF NO, DESCRIBE UNDER REMARKS BELOW.					
34. ARE MAINTENANCE COSTS NORMAL? IF NOT, EXPLAIN UNDER REMARKS BELOW.						46. ARE HYDRAULIC PUMPS, VALVES, AND FITTINGS OPERATING PROPERLY? IF NO, DESCRIBE UNDER REMARKS BELOW.					
35. ARE SAFETY DEVICES ADEQUATE AND SATISFACTORY? IF NOT, EXPLAIN UNDER REMARKS BELOW.						47. ARE ELECTRONIC SYSTEMS AND CONTROLS OPERATING PROPERLY? IF NO, DESCRIBE UNDER REMARKS BELOW.					
36. ARE INSTALLATION INSTRUCTIONS AVAILABLE FOR TRANSFER?						48. HOW MANY HOURS WAS ITEM USED BY CURRENT POSSESSOR?					
37. ARE OPERATING INSTRUCTIONS AVAILABLE FOR TRANSFER?						49. EXPLAIN UNDER REMARKS LAST USE OF EQUIPMENT DESCRIBED IN ITEM 28 ABOVE.					
38. WAS ITEM LAST USED ON A FINISHING OPERATION?						50. ESTIMATED COST FOR PACKING, CRATING, HANDLING.					
39. WILL ADJUSTMENTS OR CALIBRATION CORRECT DEFICIENCIES?						51. INDICATE DATE ITEM WILL BE AVAILABLE FOR REDISTRIBUTION.					
40. IS ITEM SEVERABLE WITHOUT DAMAGE TO COMPONENTS? IF NOT, GIVE THEIR REPLACEMENT COST.						52. CONDITION CODE.					
41. IS ITEM IN OPERABLE CONDITION?						53. OPERATING TEST CODE.					
<b>SECTION III - REMARKS</b>											
54. REMARKS											
REMARKS CONTINUED ON REVERSE SIDE <input type="checkbox"/> YES <input type="checkbox"/> NO											
<b>SECTION IV - DISPOSITION RECORD</b>											
55. CONSIGNEE (NAME AND ADDRESS, INCLUDING ZIP CODE)					56. TYPE OF DISPOSITION <input type="checkbox"/> DONATION <input type="checkbox"/> DESTRUCTION <input type="checkbox"/> SALE <input type="checkbox"/> ABANDONMENT			58a. DATE OF DISPOSITION AND PROCEEDS IF SOLD			
<b>SECTION V - VALIDATION RECORD</b>											
57. VALIDATION (TYPED NAME(S) AND SIGNATURE(S))											



<input type="checkbox"/> ACTIVE <input type="checkbox"/> INITIAL <input type="checkbox"/> IDLE <input type="checkbox"/> CHANGE				JULIAN DATE		I. D./GOVERNMENT TAG NUMBER	
<b>SECTION VI - NUMERICALLY CONTROLLED MACHINE DATA</b>							
58. CONTROL MFR			59. MODEL		60. SERIAL NO.		61. MFG DATE
62. CONTROL DESIGN <input type="checkbox"/> I.C. <input type="checkbox"/> CNC <input type="checkbox"/> STORED PROGRAM <input type="checkbox"/> EDIT <input type="checkbox"/> SOLID STATE <input type="checkbox"/> VACUUM TUBE <input type="checkbox"/> OTHER:							
63. TYPE NUMERICAL CONTROL SYSTEM <input type="checkbox"/> POSITIONING <input type="checkbox"/> CONTOURING <input type="checkbox"/> CONTOURING/POSITIONING			64. DIRECT NC <input type="checkbox"/> NO <input type="checkbox"/> YES (IF YES, "X" FOLLOWING ITEM(S)) <input type="checkbox"/> READER BY-PASS <input type="checkbox"/> MGT DATA <input type="checkbox"/> DEDICATED COMPUTER			65. AXES NAMED PER RS-267 FIGURE	
66. EIA FORMAT DETAIL							
67. EIA FORMAT CLASSIFICATION SHORTHAND		68. ROTARY MOTIONS UNDER NC (NAME AND IDENTIFY)			69. SPECIFY AXES UNDER POSITIONING CONTROL		70. SPECIFY AXES UNDER CONTOURING CONTROL
71. AXES MAXIMUM TRAVEL (ENTER AXES; X, Y, Z, ETC. AND SPECIFY INCHES OR MM)					72. POSITIONING RATE, MAX		
					73. FEED RANGE		
					ROTARY, RPM	LINEAR, XY	LINEAR, Z
74. SPINDLE DATA	A. NO. OF SPINDLES	B. NO. OF SPDL MOTORS	C. HP/SPDL MOTOR	D. TAPER	E. SPEED RANGE		F. NO. OF INCREMENTS
G. TAPE CONTROL <input type="checkbox"/> YES <input type="checkbox"/> NO							
75. EIA ASSIGNED "G" FUNCTION CODES (IDENTIFY FUNCTIONS IN REMARKS THAT ARE NOT EIA ASSIGNED)							
76. EIA ASSIGNED "M" FUNCTION CODES (IDENTIFY FUNCTIONS IN REMARKS THAT ARE NOT EIA ASSIGNED)							
77. INPUT DATA	A. STANDARD <input type="checkbox"/> RS-273 <input type="checkbox"/> RS-274 <input type="checkbox"/> RS-326		B. FORMAT <input type="checkbox"/> WORD ADD <input type="checkbox"/> TAB SEQ <input type="checkbox"/> FIXED SEQ <input type="checkbox"/> CL DATA		C. CODE <input type="checkbox"/> RS-244 <input type="checkbox"/> RS-358 <input type="checkbox"/> BINARY		D. DIMENSIONAL INPUT <input type="checkbox"/> INCH <input type="checkbox"/> METRIC <input type="checkbox"/> BOTH
	78. TOOL CHANGE DATA		A. NO. OF TURRETS	B. NO. STATIONS EA	C. AUTOMATIC CHANGER <input type="checkbox"/> YES <input type="checkbox"/> NO	D. NO. OF TOOLS	E. SELECTION <input type="checkbox"/> SEQUENTIAL <input type="checkbox"/> RANDOM
79. ROTARY TABLE DATA	A. INDEXING <input type="checkbox"/> MANUAL <input type="checkbox"/> NC		B. NO. OF STOPS		C. POSITIONING, NC <input type="checkbox"/> YES <input type="checkbox"/> NO		D. NO. OF POSITIONS
	E. CONTOURING, NC <input type="checkbox"/> YES <input type="checkbox"/> NO		F. FEED RANGE, RPM				
80. NO. OF READERS	81. READER TYPE <input type="checkbox"/> MECH <input type="checkbox"/> PHOTO <input type="checkbox"/> OTHER:		82. READER SPEED		83. INTERPOLATION <input type="checkbox"/> PARABOLIC <input type="checkbox"/> LINEAR <input type="checkbox"/> CIRCULAR <input type="checkbox"/> NONE		84. BUFFER STORAGE <input type="checkbox"/> YES <input type="checkbox"/> NO
85. THREADCUTTING MAX. LEAD.							
86. CUTTER DIA. COMPENSATIONS		87. TOOL OFFSETS		88. READOUTS			
NUMBER OF	MAX. AMOUNT	NO. OF TOOL OFFSETS	MAX. AMOUNT	<input type="checkbox"/> SEQ. NO. <input type="checkbox"/> POSITION <input type="checkbox"/> COMMAND DATA <input type="checkbox"/> OTHER:			
89. FEEDBACK DEVICE <input type="checkbox"/> ANALOG <input type="checkbox"/> NONE <input type="checkbox"/> DIGITAL		90. MIN. PROGRAMMABLE INCREMENT		91. MOTOR DRIVE <input type="checkbox"/> STEPPING <input type="checkbox"/> DC <input type="checkbox"/> HYDRAULIC		92. POST PROCESSOR (NAME)	
93. DEVELOPED BY (NAME)			94. COMPUTER LANGUAGE USED		95. PART PROGRAM LANGUAGE		96. APPLICABLE COMPUTER (NAME, MODEL & MIN CORE STORAGE)
97. REQUIRED MANUALS (TITLE AND MANUAL EDITION)							
98. REMARKS (FEATURES NOT COVERED ABOVE, FUNCTIONS NOT EIA ASSIGNED, ETC.)							

 REMARKS CONTINUED ON REVERSE SIDE   ☐ YES   ☐ NO

MIL-M-80255  
6 March 1978  
~~SUPERSEDING~~  
MIL-M-80139A  
21 December 1973

## MILITARY SPECIFICATION

### MACHINING CENTERS, VERTICAL, SINGLE SPINDLE, COMPUTER NUMERICAL CONTROL (CNC)

This specification is approved for use by all Departments and Agencies of the Department of Defense.

#### 1. SCOPE

1.1 Scope. This specification covers computer numerically controlled (CNC), single vertical spindle type machining centers, with a compound worktable, automatic tool changer, and other components or equipment as described herein.

1.2 Classification. The machining centers covered by this specification are of the following classes, sizes, and styles. Covered are machine control unit (MCU) classes for 2 and 3 axes controls, machine sizes for 5 through 20 horsepower spindle motors, and machine styles for 15 through 60 tool capacity tool changers. Also covered is an additional MCU axis and machine rotary table which may be optionally specified (see 3.4.10.1.4). The class, size and style machining center to be supplied shall be as specified (see 6.2.1).

Class A - 2 axes	(x-y)	positioning/contouring MCU
Class B - 3 axes	(x-y-z)	positioning/2 axes (x-y) contouring MCU
Class C - 3 axes	(x-y-z)	positioning/contouring MCU

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Defense Industrial Plant Equipment Center, Memphis, Tennessee 38114, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FSC 3408

Figure D-10

	<u>Spindle motor horsepower</u>	<u>Mill capacity, Cubic inches/minute (SAE 1020 steel)</u>	<u>Tape controlled travel x-y-z, inches</u>
Size 1	5	5	40-20-8
Size 2	7	7	40-20-10
Size 3	7	7	50-26-10
Size 4	10	10	40-20-12
Size 5	10	10	50-26-12
Size 6	10	10	80-26-12
Size 7	15	15	54-28-14
Size 8	20	20	54-28-24

Style A - Tool changer capacity of 15 or more tools  
 Style B - Tool changer capacity of 20 or more tools  
 Style C - Tool changer capacity of 30 or more tools  
 Style D - Tool changer capacity of 40 or more tools  
 Style E - Tool changer capacity of 60 or more tools

## 2. APPLICABLE DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on date of invitation for bids or request for proposal form a part of this specification to the extent specified herein.

### SPECIFICATIONS

#### MILITARY

MIL-M-18058 Machinery, Metal and Woodworking,  
Preparation for Delivery

### STANDARDS

#### MILITARY

MIL-STD-461 Electromagnetic Interference Characteristics  
Requirements for Equipment

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

**OCCUPATIONAL SAFETY AND HEALTH ACT (OSHA) OF 1970**

Title 29, Code of Federal Regulations, Chapter XVII, Part 1910, and amendments	Occupational Safety and Health Administration Standards
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**NATIONAL BUREAU OF STANDARDS (NBS)**

**Handbook H-28 - Screw-Thread Standards for Federal Services**

(Application for copies should be addressed to the Superintendent of Documents, Government Printing Office, Washington, DC 20402.)

**AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)**

ANSI X3.9	FORTRAN
ANSI X3.37	Programming Language APT

(Application for copies should be addressed to the American National Standards Institute, Dept. 969, 1430 Broadway, New York, NY 10018.)

**NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) STANDARDS**

**NFPA No. 79 Electrical Standard for Metalworking Machine Tools**

(Application for copies should be addressed to the National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02110.)

**ELECTRONIC INDUSTRIES ASSOCIATION (EIA) STANDARDS**

RS-227	One-Inch Perforated Paper Tape
RS-232	Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange
RS-244	Character Codes for Numerical Machine Control Perforated Tape
RS-267	Axis and Motion Nomenclature for Numerically Controlled Machine Tools
RS-274	Interchangeable Perforated Tape Variable Block Format for Positioning, Contouring, and Contouring/Positioning Numerically Controlled Machines
RS-281	Electrical and Construction Standards for Numerical Machine Control
RS-358	Subset of USA Standard Code for Information Interchange for Numerical Machine Control Perforated Tape

(Application for copies should be addressed to Electronic Industries Association, Engineering Department, 2001 Eye St., NW, Washington, DC 20006.)

NATIONAL ELECTRICAL MANUFACTURER'S ASSOCIATION (NEMA) STANDARDS

MG1 Motors and Generators

(Application for copies should be addressed to the National Electrical Manufacturer's Association, 155 East 44th St., New York, NY 10017.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. REQUIREMENTS

3.1 First article. When specified (see 6.2.1), the contractor shall furnish one complete machining center for first article inspection and approval (see 4.2 and 6.4).

3.2 Design. The machining center shall be new and one of the manufacturer's current models. Its design shall include features and components necessary for maintaining alignment and accomplishing drilling, tapping, milling, and boring performance required herein. The machine shall have a vertical axis spindle assembly housed within a machining head which shall be supported by a column and floor mounting base. The base shall also support a saddle and worktable which shall be arranged to support and secure the workpiece in the machining operations. The worktable or column shall have lateral slide motion (travel) as necessary for altering the relationship of the spindle with the workpiece in the x and y axes. Unless otherwise required, z axis movement shall be accomplished by either a machining head or machining head and quill, sliding vertically along the column ways to and from the worktable or with the machining head affixed to the column and by a quill sliding within the head and to and from the worktable. Tools, toolholders, and adapters shall be inserted and removed from the spindle by a tool changer with storage magazine. Tool change, spindle operation, and motion in the x, y, and z axes shall be directed by a numerical control system with a computer numerical control (CNC) type MCU, axis servo drives, and feedback devices. System axes configuration shall be in accordance with 3.4.10.1 for the applicable MCU class required by the contract or order. The machine and its numerical control system shall constitute a completely functional system with built-in operations programmed by coded punch tape. The machine functions shall be controlled by manually operated control devices, semi-automatically by manual data input devices, and automatically from tape input and part programs in data memory. All parts of the machine or system that are subject to wear, breakage, or distortion shall be accessible for adjustment, replacement and repair.

**3.2.1 Operating controls.** Operating controls for the machining center shall be arranged on the MCU console or machine pendant. Controls such as push-buttons, dials, and switches shall be functionally arranged and clearly identified to facilitate use.

**3.2.2 Safety and health requirements.** Covers, guards, or other safety devices shall be provided for all parts of the machine that present safety hazards. The safety devices shall not interfere with the operation of the machine. The safety devices shall prevent unintentional contact with the guarded part, and shall be removable to facilitate inspection, maintenance and repair of the parts. All machine parts, components, mechanisms, and assemblies furnished on the machine, whether or not specifically required herein, shall comply with all of the Standards promulgated under OSHA that are applicable to the machine itself.

**3.2.3 Lubrication.** All bearings (except sealed-for-life type), mating gears, and sliding parts shall be provided with means for lubrication. Oil reservoirs shall be fitted with oil level sight gages. Manually operated systems for ways and remote areas shall have control handles mounted in accessible locations. All oil holes, grease fittings, and filler caps shall be easily accessible.

**3.2.4 Interchangeability.** To provide for replacement of worn parts, all parts bearing the same part number shall be functionally interchangeable without modification of part or machine, and shall be dimensionally identical within the manufacturing tolerance limits in use by their manufacturer.

**3.2.5 Reclaimed materials.** The machine shall contain reclaimed materials to the maximum extent possible without jeopardizing its intended use and performance. The reclaimed materials shall have been reprocessed, remanufactured, or recycled in a manner which restores them to the same chemical composition and physical properties as the materials originally selected for use on the machine. Reclaimed materials shall include iron, steel, copper, brass, aluminum, fiber products, plastics and elastomers that have been collected from discarded solid, liquid, semi-solid, or gaseous waste such as garbage, refuse or sludge.

**3.3 Construction.** The machine shall be so constructed that when installed and connected to power, it will be ready for operation upon filling with operating fluids. The machine shall be constructed of parts which are without defects and free of repair. The structure shall be capable of withstanding all forces encountered during operation of the machine to its maximum rating and capacity without permanent distortion.

**3.3.1 Castings and forgings.** All castings and forgings shall be free of defects, scale and mismatching. No process such as welding, peening, plugging, or filling with solder or paste shall be used for reclaiming any defective part.

**3.3.2 Welding, brazing, or soldering.** Welding, brazing, or soldering shall be employed only where specified in the original design. None of these operations shall be employed as a repair measure for any defective part.

**3.3.3 Fastening devices.** All screws, pins, bolts, and similar parts shall be installed in such a manner as to prevent change of tightness. Those subject to removal or adjustment shall not be swaged, peened, staked, or otherwise permanently deformed.

**3.3.4 Surfaces.** All surfaces of castings, forgings, molded parts, stampings and welded parts shall be cleaned and free from sand, dirt, fins, sprues, flash, scale, flux and other harmful or extraneous materials. All edges shall be either rounded or beveled unless sharpness is required to perform a necessary function. Except as otherwise specified herein, the condition and finish of all surfaces shall be in accordance with the manufacturer's standard commercial practice.

**3.3.5 Painting.** Unless otherwise specified (see 6.2.1), the machine shall be painted in accordance with the manufacturer's standard commercial practice.

**3.3.6 Threads.** Unless otherwise specified (see 6.2.1), all threaded parts shall conform to Handbook H28.

**3.3.7 Dials.** Unless otherwise specified (see 6.2.1), feed screw dials shall be graduated in either the inch or metric (SI unit) system. Graduations to indicate stock removal or tool movement shall be in increments of not more than 0.001 inch or the equivalent on the metric scale. The size of dial faces shall be such that the graduations are easily read. Dial faces shall be permanently and legibly engraved, stamped, or etched, and shall have a non-glare finish.

**3.3.8 Plates.** All words on speed and feed indicating plates and on instruction plates shall be in the English language, engraved, etched, embossed or stamped in boldface characters on a contrasting background.

**3.3.9 Gears.** Unless otherwise specified (see 6.2.1), the gears used in the machine shall be machined in either the inch or metric (SI unit) system. In either case, the gears shall be suitable for the intended purpose, and shall be heat treated by a process that will impart the necessary toughness and hardness that will enable the gear train to transmit full rated torque without failure or premature wear.

**3.4 Components.** The machining center shall include components consisting of a base, column, saddle, worktable, machining head, spindle assembly, tool changer, coolant system, electrical system, and numerical control system.

**3.4.1 Base.** The base shall be a casting of iron or iron alloy or a fabricated steel weldment, ribbed and braced to minimize distortion and deflection. The base shall form a foundation for the entire machine and be integrally constructed with the column or be separately constructed with the column machined, securely attached, and in either case, be sufficiently rigid to maintain mutual component alignment for assuring accuracy required herein. The base shall have guideways that are proportioned to fully support the saddle throughout its full range of travel. The base shall have means for leveling the machine on a flat mounting surface. Hydraulic or coolant fluid reservoirs may be housed within the base or be supplied as separate external units. Reservoirs shall have means for indicating fluid levels. The base shall have access or removable plates as necessary for servicing components housed within.

**3.4.2 Column.** The column shall be a casting of iron or iron alloy or a fabricated steel weldment of box-like construction, internally ribbed and braced to minimize distortion and deflection under normal tool loads. The column shall be designed to support and accommodate the machining head and have guideways to facilitate vertical movement of the head or worktable.

**3.4.3 Saddle.** The saddle slide shall be a casting of iron or iron alloy or a fabricated steel weldment, rigidly constructed and precision fitted to the guideways of the base. The saddle shall also have guideways for supporting and traversing the worktable throughout its full range of travel. Guideways of the saddle and all other components of the machine shall be designed with friction characteristics that will permit precise control of slide movement without sticking or overshooting. When specified (see 6.2.1), the guideways of the machines supplied with the Class B or C MCU's, shall be hardened and ground. Mating ways shall have means for holding them in alignment to prevent cutting forces from separating slide surfaces or distorting feed screws. Means such as servolocks shall be provided that automatically secure slide surfaces in place immediately upon completing numerical control directed moves. The guideways shall be shielded from chips, coolant fluid and other contaminants by telescoping metal covers or similar means.

**3.4.4 Worktable.** The worktable shall be a casting of iron or iron alloy, internally ribbed and proportioned to support and withstand maximum capacity workpiece weights and tool thrust loads. The worktable shall be precision fitted to the ways of the saddle and be the compound type, arranged to provide workpiece travel in x and y axes. The top of the worktable shall be machine finished for a work mounting surface. The worktable shall have a coolant trough or similar means for draining spent coolant into its reservoir. Unless otherwise specified (see 6.2.1), T-slots, their number and configuration in the worktable top, shall be the manufacturer's standard. When required, the worktable shall be furnished with a sub-plate of the characteristics specified (see 6.2.1).



**3.4.5 Machining head.** The machining head shall be a casting of iron or iron alloy or a fabricated steel weldment designed and proportioned to house and support the quill (as required), spindle assembly, and spindle rotational drive with motor and related components necessary for accomplishing drilling, tapping, milling, and boring required herein. The machining head shall hold the spindle in axial alignment perpendicular to the work mounting surface of the worktable and shall be designed to prevent distortion to the head due to torsional forces of the drive. Unless otherwise specified (see 6.2.1), z axis movement shall be accomplished by either a machining head or a machining head and quill sliding vertically along the column ways to and from the worktable or with the machining head affixed to the column and by a quill sliding within the machining head and to and from a worktable. In the latter case, the worktable shall also be vertically adjustable. On machines supplied with the Class A MCU, z axis movement shall be power driven independently of the spindle drive and be controlled manually and by an automatic feed cycle as required by 3.4.10.1.1. In addition, not less than 20 program selectable and micrometer or electronically adjustable depth stops shall be provided. On machines supplied with the Class B or C MCU's, z axis movement shall be servo driven and be fully controlled by the numerical control system. The machine shall have stops that are located at the upper and lower extremes of z axis travel to prevent excessive overtravel.

**3.4.5.1 Spindle assembly.** The spindle shall be of alloy steel hardened and ground to a finish not rougher than 32 microinches. The spindle shall be supported and held in axial and radial alignment by ball or roller bearings. The spindle shall be mounted in the machining head with its bearings designed and arranged to compensate for thermal expansion. The spindle shall have positive means for accepting, retaining and releasing tools and tool holders inserted by either the automatic tool changer or the operator. Unless otherwise specified (see 6.2.1), noses, bores, and other characteristics of the spindle shall be the manufacturer's standard. The spindle shall be equipped to orient the automatically inserted tools to maintain the same radial position they occupied in the tool changer. The machine shall drive the spindle in both the clockwise and counterclockwise directions of rotation for accomplishing the full range of spindle speeds specified herein. The machine shall be arranged to automatically stop spindle rotation for tool change. The machine shall have overload protection which automatically stops the movement of all slides and the rotation of the spindle should it stall from overload.

**3.4.6 Tool changer.** The machine shall have an automatic tool changer with a magazine that is capable of storing not less than the tool capacity required for the style machine specified in the contract or order. The magazine shall be of the rotary drum design or of any other closed loop recirculating configuration with the capability of presenting a preprogrammed tool to the tool changer for exchange with the tool held in the spindle

at the time of program commands for tool change. Tool change shall be accomplished by means of a power-actuated mechanism which shall interchange the tool in the spindle with a tool selected from the tool magazine. The magazine shall permit convenient loading and unloading of tools, tool holders, and adapters during operational set-up. The tool changer shall be arranged for random tool selection which shall include the capability of reusing a tool that has been returned to the magazine after a program operation.

**3.4.7 Coolant system.** Unless otherwise specified (see 6.2.1), the machine shall be supplied with a complete flood and mist type coolant system with numerically controlled selection of coolant type and on/off of coolant flow. The system shall have adequate capacity for all types of machining operations for which the machine is designed and shall have means for regulating the flow of flood coolant and for adjusting mist coolant supply as required. All components necessary to make the system completely functional shall be furnished including reservoirs, chip screens, filters, drain troughs, and clean-out plates.

**3.4.8 Hydraulic system.** The hydraulic system, when supplied, shall be complete with pumps, valves, piping, cylinders, reservoir and pressure controls. Overpressure protection shall be provided on the high pressure line from the hydraulic pump to prevent damage to components. The system shall include filters to insure delivery of clean fluid. The reservoir shall have a sight gage to indicate the fluid level. The fluid temperature shall be maintained within the proper operating range during all normal operations of the machine. When required, noise level and noise suppression enclosures for stand-alone hydraulic units shall be as specified (see 6.2.1).

**3.4.9 Electrical system.** Unless otherwise specified (see 6.2.1), the electrical system shall conform to NFPA No. 79. Unless otherwise specified (see 6.2.1), the machine shall operate from a 230/460 volt, 3 phase, 60 Hz source and shall be initially wired for operation on 230 volts. An identified terminal shall be provided, suitable for connection of a grounding conductor.

**3.4.9.1 Motors and motor accessories.** Motors shall have ball or roller bearings and shall be rated for continuous duty. Motors shall be either AC 3 phase, 60 Hz, or industrial DC motors conforming to NEMA Standard MG1 and equipped with solid state rectifiers, or shall be stepping type motors with not less than 50 incremental steps per revolution. Unless otherwise specified (see 6.2.1), each electric motor shall meet the requirements of a dripproof enclosure.

**3.4.10 Numerical control system.** The machining center shall have a fully automatic numerical control system with machine control unit (MCU), axis servo drives, and position feedback devices. The system shall control the machine to accomplish axis movement, spindle operation, tool change, and all other part program directed functions for machining centers of the type specified herein. The MCU shall be a continuous path contouring unit capable of accepting binary coded perforated tape input and translating it into the motion command signals as well as the auxiliary functions of the programs. The MCU shall be a mini-computer or soft-wired microprocessor system of the computer numerical control (CNC) type, having software programmable internal data memory and program edit capability. The MCU shall be selectively operated either by tape reader input through buffer storage, by programs in data memory, or by manual data input (MDI). The system shall control the axis servo drives to move the controlled elements to the program commanded positions with the MCU regulating speed, direction, sequence and dwell. The system shall position the controlled slides in rapid traverse, feed in any controlled axis at the program feed rate, select spindle speed and direction of rotation, initiate tool change, and control the flow of coolant fluid. Movement in the x, y, and z axes shall be actuated through a closed loop electric, hydraulic, or electro-hydraulic servomechanism with variable speeds. The feed drive of all slides under numerical control shall be accomplished by anti-backlash ball lead screws with preloaded recirculating ball nuts. The z axis feed drive of the machines supplied with the Class A or B MCU's may be accomplished by a rack and pinion or rack and worm type drive. Unless otherwise specified (see 6.2.1), the system shall have either resolver or encoder type position feedback devices. The feedback devices shall provide the MCU with position feedback signals in order that they may be compared with the control output and the machine slides moved in the direction that will tend to reduce the difference to zero. Input resolution of system resolvers shall be not greater than 0.0001 inch.

**3.4.10.1 Numerically controlled axes.** With machine axis and motion nomenclature assigned in accordance with EIA RS-267, the system shall be configured for the combination of point-to-point positioning and continuous path contouring axes of motion as required for the class MCU specified in the contract or order. Positioning axes shall execute program movement at fixed or programmed velocities, independent of the moves of any other axis. Contouring axes shall have simultaneous start and completion of defined moves with vector and velocity control.

**3.4.10.1.1 Class A MCU.** The Class A MCU shall control the machine in the x and y axes for performing drilling, tapping, boring, reaming and contour milling operations directed by linear and circular interpolation. Z axis movement of the spindle shall be controlled both manually and by an automatic feed cycle which shall be controlled either by the MCU or separately. The automatic feed cycle shall permit the operator, after selecting and setting the rapid approach intermediate and final depth stops, to initiate the cycle for it to proceed automatically to perform a complete sequence of machining events. Preset tools shall not be required and the ability of the automatic cycle to machine multiple depths with the same tool without operator intervention, shall be provided.

**3.4.10.1.2 Class B MCU.** The Class B MCU shall function as the Class A MCU except that all Z axis movement to include rapid approach, depth limits and the feeds and speeds of the spindle shall be controlled by the MCU in a positioning mode.

**3.4.10.1.3 Class C MCU.** The Class C MCU shall function as the Classes A and B MCUs except that it shall also control the machine to perform drilling, tapping, boring, reaming and continuous path contour milling through simultaneous movements of the x, y and z axes utilizing linear interpolation and plane selectable (xy, xz and yx) circular interpolation. Unless otherwise specified (see 6.2.1), the axis that is perpendicular to the selected plane shall be directed by linear interpolation.

**3.4.10.1.4 Rotary table, a axis.** When specified (see 6.2.1), the control system shall also be configured for an a axis and the machine shall be furnished with a rotary table. The a axis control shall direct rotation of the rotary table to any of the program selectable (degree) positions specified (see 6.2.1). The rotary table shall function simultaneously with the contouring motion of the x and y axes or independent of the contouring axes as specified (see 6.2.1). The rotary table shall be either an integral component of the machine or an attachment to the worktable. The top of the rotary table shall have T-slots for workpiece attachment.

**3.4.10.2 Data memory.** System software, including part programs, operating program, fixed cycles, tool length offsets, tool diameter compensations, and resident and non-resident diagnostics, shall be stored and processed by the MCU utilizing either computer-core or micro-processor semiconductor memory. Unless otherwise specified (see 6.2.1), the MCU shall have memory capacity necessary for the storage of not less than 100 feet of multiple part program tape data in addition to the storage of all other software of the system. When required, the MCU shall also have bulk memory storage devices of either the flexible (floppy) disk or drum

type with characteristics (specific type, data capacity, etc.) as specified (see 6.2.1). Tape input shall be utilized for storing programs in memory where they shall be accessible for repetitive execution without the use of the tape reader. The MCU shall be functional for executing stored programs in conjunction with manual data input and stored data to include machine setup information, fixed cycles, and program sub-routines. The MCU shall include means for deleting programs from storage. Memory space formerly occupied by deleted programs shall be accessible for reutilization. MCU's utilizing volatile type memory shall have a self-contained emergency power source that will maintain program storage of the system for a period of not less than 72 hours. MCU's utilizing battery back-up systems, shall also have a battery charging unit.

3.4.10.2.1 Fixed cycles. When required, data memory shall include program selectable fixed cycles as defined by EIA RS-274 as specified (see 6.2.1).

3.4.10.3 Program input. The MCU shall accept, translate, and act on program instructions coded in accordance with EIA RS-244 and EIA RS-358. Primary program input medium shall be one inch, eight channel perforated tape conforming to the dimensional characteristics of EIA RS-227. Tape format shall be variable block, word address in accordance with EIA RS-274. The MCU shall be capable of processing binary coded decimal input sequentially programmed in either incremental departures, absolute coordinates, or a combination of both. The MCU shall direct linear axes motion from dimensional input preceded by plus (+) or minus (-) signs and be switchable either by program command or by manual means for accepting inch or metric (SI Unit) input. The maximum departure for a single command shall be not less than + 99.9999 inches. The smallest programmed increment shall be not more than 0.0001 inch. When required, the MCU shall be arranged to receive program input from a remote data source (main frame computer, edit system, etc.) as specified (see 6.2.1). Arrangements shall include a switch or similar means that will enable the tape reader to be bypassed for entering program data from the specified remote source.

3.4.10.3.1 Auxiliary functions. The MCU shall respond to all program commanded auxiliary functions including those required by the procuring activity (see 6.2.1). System preparatory and miscellaneous functions shall be coded in accordance with EIA RS-274, Appendix B. Preparatory functions shall include interpolation, fixed cycles, and dwell. Miscellaneous functions shall include program stop, optional program stop, end of program, spindle CW, spindle CCW, spindle off, coolant on, coolant off, tool change, end of program (rewind) and program re-start.

**3.4.10.3.2 Tape reader.** The MCU shall have a photoelectric type tape reader for holding, feeding and reading one inch, eight channel, perforated tape as required herein. The tape reader shall be located on the exterior of the MCU, in a position that is readily accessible, visible, and protected from environmental contaminants. The reading speed of the tape reader shall be not less than the capability of the MCU to receive and process input data and in any event, not less than 150 characters per second. Unless otherwise specified (see 6.2.1), the reader shall be furnished with tape reels that are capable of accommodating not less than 600 feet of tape. The MCU shall have controls for feeding, rewinding, and stopping the tape for single and multiple block operation to include stored program and sequence number search.

**3.4.10.3.3 Parity check.** The MCU shall have a parity check system which stops the tape reader and illuminates an error indicating light on the control panel or produces an error message on the CRT or readout when the number of holes read in a traverse row of tape data does not comply with the program character code (EIA RS-244 or EIA RS-358). The system shall include controls for overriding parity error.

**3.4.10.3.4 Feed hole verification.** The MCU shall have a feed hole verification system which shall stop the tape reader and illuminate an error indicating light on the control panel or produce an error message on the CRT or readout when, during the reading of each traverse row of data, the feed holes of the tape are not present.

**3.4.10.3.5 Block delete.** The MCU shall have a block delete system which can be controlled by the operator for reading through or ignoring blocks of tape data.

**3.4.10.3.6 Buffer storage.** The MCU shall have buffer storage for transferring blocks of program data from the tape reader to internal storage without delaying the next incoming block or interrupting the active command function. The buffer shall delay or store input data until allocated by the controlling devices. The buffer shall store one or more blocks of program data.

**3.4.10.4 Manual data input (MDI) and display.** The MCU shall be arranged to display and accept manually inserted data for all machine and MCU functions that are controlled through the tape medium. MDI shall be accomplished through an alpha-numeric keyboard and other pushbuttons as necessary for displaying and inserting keyboard selected addresses. Unless otherwise specified (see 6.2.1), data to be viewed or input shall be displayed in alpha-numeric form on either a cathode ray tube (CRT) or a universal readout with display capacity of not less than 250 characters. Along with the MDI entries, the CRT or readout(s) shall be selectively or

automatically controlled to also display data to include active program commands, actual position of each axis, one or more blocks of buffer data, active sequence number, tool number in the spindle, spindle speed and feed rate, tool length offsets and cutter diameter compensation data, stored program index, operator instructions and status messages, MCU malfunction warnings and fault messages, and diagnostic test data.

**3.4.10.4.1 Program edit.** Unless otherwise specified (see 6.2.1), the MCU shall be configured with an edit mode that is operational through the MDI keyboard and other controls as necessary for the display and modification of program data of tape being input and programs stored in memory. The mode shall include controls for searching the selected data input source (tape or data memory) both forward and reverse and block-by-block for a designated sequence number or block of program data. When located, the designated block shall be displayed for review and editing. The mode shall permit data to be deleted, altered, and additional blocks inserted between blocks of program data. It shall also permit the edited data of tape programs to be input to data memory and merged with the programs for tape execution. The MCU shall include a tape punch output interface with necessary hardware and software for causing the coded data of stored programs to be produced by a tape punch unit. In order to facilitate punch unit connection, the interface shall include necessary circuitry and a plug receptacle in accordance with EIA RS-232.

**3.4.10.4.2 Tape punch unit.** When specified (see 6.2.1), the system shall have a tape punch unit for producing punched tapes from edited programs of tape being input and from programs stored in data memory. The unit shall have a plug receptacle and circuitry that is compatible with the tape punch output interface required above for receiving signals and punching both paper and mylar tapes of dimensional characteristics and coded in accordance with 3.4.10.3. The punching speed of the unit shall be not less than 75 characters per second.

**3.4.10.5 MCU console.** The MCU console shall be constructed in accordance with the applicable requirements of EIA RS-281. The MCU shall be a solid state, soft wired, integrated circuit, and modular type unit. The console shall have a control panel for displaying the visual signals and operating controls of the system and machine. The console shall have removable panels or other means that provide access to all circuit boards, wiring and other components contained within. Circuits shall include tagged or color-coded wiring, terminal board markings, and branch circuit fusing. The MCU shall include electrical and safety interlocks as required for the protection of the system, machine, and the operator. The console

shall be sealed to protect the contained components from dust or other environmental matter that could adversely affect performance of the MCU. The system shall function effectively and accurately within any ambient temperature ranging between 50 and 120 degrees Fahrenheit and in a relative humidity up to 95 percent.

**3.4.10.5.1 Spindle speed override.** The MCU, or pendant, shall have a spindle speed override control with indicator for manual adjustment of the tape and stored program commanded spindle speed rate from 60 percent or less to 100 percent or more in continuous adjustment or in not more than 10 percent increments.

**3.4.10.5.2 Feed rate override.** The MCU, or pendant, shall have a feed rate override control with indicator for manual adjustment of the tape or stored program commanded feed rate for each axis controlled by the numerical control system. The override shall provide adjustment from 0 to not less than 120 percent in continuous adjustment or in not more than 10 percent increments. Z axis feed rate for the Class A shall be controlled both manually and by an automatic feed cycle (see 3.4.10.1.1).

**3.4.10.5.3 Axis jog.** Unless otherwise specified (see 6.2.1), the MCU, or pendant, shall have manual controls for accomplishing both single and continuous, low and high speed jog movements of the slides for each controlled axis in both the plus and minus directions.

**3.4.10.5.4 Full floating zero.** The MCU shall have controls for locating the zero reference (set) point at any position throughout the range of departure for each controlled axis.

**3.4.10.5.5 Interpolation.** The MCU shall have linear and circular interpolation capability for directing contouring cuts by simultaneous incremental or absolute movements of any or all axes controlled (see 3.4.10.1). Circular interpolation shall provide a means within the system for generating an arc in any one quadrant using one block of program data. Direction of the tool center arc shall be clockwise or counterclockwise and shall be selected by a preparatory function of the program.

**3.4.10.5.6 Mirror image.** The system and machine shall produce right or left hand parts from the same program through the use of axes inversion switches or MDI keyboard. Mirror image shall not affect the direction or sense of manual controls.

**3.4.10.5.7 Tool length offsets and cutter diameter compensations.** When specified (see 6.2.1), the MCU shall be configured with the specified number of tool length offsets ranging up to + 79.9999 inch and cutter diameter compensations ranging from not more than + .0001 inch to + 1.0000 inch. Tool length offsets and cutter diameter compensations shall be displayed on the CRT or readouts and be input through the MCU keyboard.



3.4.10.6 **Diagnostics.** The MCU shall have resident diagnostics that constantly monitor the system during operation for the purpose of detecting electrical component malfunction and operating fault conditions. Diagnostics shall detect faults, halt the system function, and display a message or illuminate a signal light for fault conditions including memory parity errors, axis servo failures, tape reader errors, over-travel, overheated MCU, and others. The system shall also be furnished with non-resident diagnostics, consisting of manuals and program routines with test tapes that can be input through the tape reader for isolating system faults in the event of a failure. The diagnostics shall set-up the MCU for testing, and thoroughly exercise the system for isolating and identifying faults down to circuit board level, and then display an appropriate message or fault code that advises the operator of the conclusion of the test, other test, or remedial action necessary. Fault codes shall be identified and defined in the diagnostic manuals. The manuals shall provide detailed technical descriptions of the diagnostic procedures complete with diagrams of all circuits of the system.

3.4.10.7 **Postprocessor.** Unless otherwise specified (see 6.2.1), the system shall be furnished with a postprocessor program(s) to be utilized in off-line computer assisted preparation of part programs. The postprocessor shall be designed for use with the current version of the Automatic Program Tool (APT) system conforming to ANSI X3.37, and be written in FORTRAN IV language, conforming to ANSI X3.9, for acceptance by the computer (name and model) specified (see 6.2.1). The postprocessor shall accept the preprocessed data of the APT Center Location (CL) tape, and while taking into account the slide dynamics and geometric constraints of the machine, it shall process or convert the data into an operating program (tape) that is acceptable to the input format of the system for operating the machine to accomplish performance specified herein. In addition, the postprocessor shall be capable of processing all program-mable functions for which the combination numerical control system machines are designed. The postprocessor shall be arranged with tables and adjustable parameters in each area where future changes or modifications may be required. The postprocessor shall be documented as follows:

- a. Complete mathematical analysis for all equations.
- b. Methods of handling round-off.
- c. Flow diagrams.
- d. Postprocessor design theory.
- e. Vocabulary and its function.
- f. Implementation procedures.
- g. Compilation listings.
- h. Description as to the purpose, use, and function of each variable used in the postprocessor.
- i. Description of COMMON usage with each variable's position in COMMON indicated.
- j. Source code for all software shall be provided via a mutually acceptable media.

Each subroutine shall contain sufficient comment cards at the start of each subroutine to describe the following:

- a. Purpose of subroutine.
- b. Purpose and function of variables in the calling sequence.
- c. The input and output variables used in the subroutines.
- d. Error codes that are generated within the subroutine.
- e. The calling subroutine(s).

Each subroutine shall also contain embedded comment cards in sufficient quantity and appropriately placed to describe the logic and processing. If overlays are used, then written descriptions of the purpose and function of the overlay, as well as the subroutines used in the overlay, shall be provided. A written list of all error and warning diagnostics generated by the postprocessor shall be provided.

**3.4.10.7.1 Postprocessor validation.** Unless otherwise specified (see 6.2.1), the postprocessor, complete with all required documentation, shall be furnished to the using activity for computer compatibility verification and validation 30 days prior to delivery of the machining center or within the time designated in the contract or order. The postprocessor will be tested by the Government to insure that it is compatible with the computer configuration specified in the contract or order, for producing operating programs (tape) that are acceptable to the numerical control system/machine combination for accomplishing all programmable functions for which they are designed. Also, a test program, complete with tape(s) and manuscript that has been produced from the postprocessor and is written to fully demonstrate all machining operations of the machining center, shall be furnished. The operations shall include each of the functional characteristics required by Table I for the machining head, spindle, worktable, and tool changer along with each of the auxiliary functions required by 3.4.10.3.1. Functional characteristics for multiple speeds and feeds may be programmed to accomplish only the lowest, highest, and not less than 5 intermediate settings. All postprocessor and test program errors detected shall be corrected by the supplier before validation.

**3.4.11 Standard equipment.** Unless otherwise specified (see 6.2.1), the following equipment shall be furnished with the machine:

- a. A load meter installed on the machine or MCU console that constantly registers the horsepower load (horsepower units or percent of load) on the spindle rotational drive motor.
- b. A complete operating supply of hydraulic fluid for installation at the user activity's facility, when the machine is supplied with a hydraulic system.
- c. One set of wrenches, operating and repair tools that are normally furnished by the manufacturer.

3.4.12 Optional equipment. The following optional equipment shall be furnished as specified (see 6.2.1).

- a. A worklight, conveniently mounted to illuminate the work area, complete with protective shield and on-off switch.
- b. An elapsed time indicator of the non-reset type, with digital readout and designed to resist the effects of vibration, voltage fluctuation, temperature change, and humidity. The indicator shall be mounted on the machine in a position visible and operable from the operator's station and be connected to record and accumulate machine operating time to not less than 9999.9 hours.
- c. Tools, tool holders, and adapters, as specified.
- d. Other optional equipment as specified.

3.5 Sizes and capacities. The sizes and capacities of the machining-center shall meet the requirements of Table I as applicable for the machine size specified in the contract or order.

3.6 Performance. The machine and numerical control system combination shall be capable of performing as specified herein. In addition, the machine shall be capable of performing drilling, tapping, milling and boring to accomplish the capacities of Table I while meeting the accuracies of Table II.

3.7 Alignment. The machine and numerical control system shall meet the alignment and accuracy tolerances of Table III.

TABLE 1. Sizes and Capacities.

CHARACTERISTIC	REQUIREMENT 1/							
	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6	Size 7	Size 8
Spindle Motor Horsepower	5	7	7	10	10	10	15	20
z axis travel, inches	40	40	50	40	50	80	54	54
z axis travel, inches	20	20	26	26	26	26	28	28
Capacity (in SAE 1020 steel):	8	10	10	12	12	12	14	24
Top, dia., inches	1	1-1/4	2	1-3/4	1-3/4	1-3/4	2	2
Mill, cubic in. per min.	1-1/4	1-1/4	2	1-1/2	1-1/2	1-3/4	2	2
Machining head & spindle assembly:	5	7	7	10	10	10	15	20
Spindle speed range, RPM	12	32	80	32	32	32	32	50
Spindle feeds, number, machines supplied with:	80 to 2000	80 to 2000	45 to 3000	45 to 1500	70 to 3000	70 to 3000	30 to 3000	30 to 3000
Class A MCUs	55	55	55	N/A	N/A	N/A	N/A	N/A
Classes B or C MCUs	inf.	inf.	inf.	inf.	inf.	inf.	inf.	inf.
Spindle feed rate range, in. per min., machines supplied with:								
Class A MCUs	0.5 to 20	0.5 to 20	0.5 to 20	N/A	N/A	N/A	N/A	N/A
Classes B or C MCUs	0.5 to 90	0.5 to 100	0.2 to 100	0.5 to 200	0.5 to 200	0.5 to 200	0.5 to 200	0.5 to 150
Spindle travel (z axis), in. 2/	8	10	10	12	12	12	14	24
Spindle rapid traverse rate, in. per min.	80	100	200	200	200	200	200	200
Machining head or worktable vertical travel (z axis), in.	8	10	10	15	20	20	20	20
Machining head or worktable vertical rapid traverse rate, in. per min.	80	100	200	200	200	200	200	200
Worktable:								
Work mounting surface, length x width, in.	48 x 20	42 x 22	54 x 26	44 x 20	54 x 26	80 x 26	60 x 28	60 x 28
Load capacity, lbs.	1000	2000	2500	2500	3000	3500	3500	3500
Worktable (saddle or column) travel, in.								
x axis	40	40	50	40	50	80	54	72
y axis	20	20	26	20	26	26	28	28
Rapid traverse rate, in. per min.	120	150	200	200	200	200	200	200
Milling feeds, number	inf.	inf.	inf.	inf.	inf.	inf.	inf.	inf.
Milling feed rate range, in. per min.	0.5 to 90	0.5 to 100	0.2 to 100	0.5 to 200	0.5 to 200	0.5 to 200	0.5 to 200	0.5 to 100
Chip load (consecutive operations two different tools in the ready position), seconds	12	12	12	12	12	12	12	12

1/ Requirements are not less than those shown except as otherwise indicated above. Where a range is shown, the required performance is from the smaller figure or less to the larger figure or more.

2/ z axis travel of machines supplied with the Class A MCU shall be controlled both manually and by an automatic feed cycle. (see 3.4.10.1.1).

TABLE II - Performance Accuracy.

MACHINING OPERATION	ACCURACY (Permissible tolerance)
<u>Drilling:</u> Depth of hole - Class A MCU Classes B and C MCU	$\pm 0.002"$ $\pm 0.001"$
<u>Tapping:</u> Threaded holes shall be Class III fit in accordance with Handbook H28	
<u>Boring and Counterboring:</u> Hole location, based on centerline distance of bored holes, 2 holes, 18" apart Hole size, maximum spread, hole to hole Depth of counterbore - Class A MCU Class B MCU Class C MCU	$\pm 0.002"$ $\pm 0.002"$ $\pm 0.003"$ $\pm 0.002"$ $\pm 0.001"$
<u>Milling (straight-line):</u> Squareness of sides Parallelism of opposing sides Flatness Angularity of ramp cuts - Classes B and C MCU Corner location, deviation from programmed points	$0.002"/FT$ $0.002"/FT$ $\pm 0.002"/3 FT$ $\pm 0.002"/FT$ $\pm 0.001"$
<u>Contouring (circle):</u> Roundness Diameters measured at 30 degree intervals Radii measured at 30 degree intervals Surface finish, maximum roughness Angularity, difference between programmed and actual points of tangency of circles to straight surfaces	$\pm 0.002"$ $\pm 0.002"$ $64 RMS$  $0.002"$
<u>Contouring (straight-line):</u> Squareness of sides Angularity of sides	$0.002"/FT$ $0.002"/FT$

TABLE III - Alignment and Accuracy.

COMPONENT CHARACTERISTIC	PERMISSIBLE TOLERANCE
<u>Worktable:</u>	
Flatness of work mounting surface	0.001"/FT
Squareness of work mounting surface to spindle axis, in any 6" sweep radius	0.0020"/FT
Motion in the x axis, rise and fall with respect to the spindle	0.001"/FT
Motion in the y axis, rise and fall with respect to the spindle	0.001"/FT
Parallelism of T-slots with x axis movement	0.0005"/FT
Squareness of T-slots with y axis movement (slide travel squareness)	0.0005"/FT
<u>Spindle:</u>	
Axial runout:	0.005" TIR
Radial runout:	
1" from spindle nose	0.0005" TIR
6" from spindle nose	0.0015" TIR
Squareness of spindle movement to the work mounting surface of the worktable per 6" of travel	0.0005"
<u>Numerical control system:</u>	
x & y axes positioning and repeatability accuracy:	1/ + 0.001"/FT
All MCU classes: absolute positioning	± 0.0005"
position repeatability	
z axis positioning and repeatability accuracy:	
Class A MCU, positioning repeatability	+ 0.003"
Class B MCU, absolute positioning	± 0.002"/FT
positioning repeatability	± 0.0005"
Class C MCU, absolute positioning	± 0.001"/FT
positioning repeatability	± 0.0005"
a axis (when furnished) positioning and repeatability accuracy:	
Absolute positioning	+ 10 sec./FT
Positioning repeatability	± 5 sec.
Axis overshoot:	
20% of maximum feed rate	0.003"
Maximum feed rate	0.005"

1/ Not to exceed 0.0025" in overall travel.

3.8 Electromagnetic interference control. When specified (see 6.2.1), equipment procured under this specification shall comply with the requirements of MIL-STD-461.

3.9 Fungus control. When required (see 6.2.1), fungus proofing shall be as specified.

3.10 Lubrication chart or plate. Unless otherwise specified (see 6.2.1), a lubrication chart or plate shall be permanently and securely attached to the machine. If a chart is furnished, it shall be placed in a transparent plastic folder or permanently sealed between clear plastic sheets with suitable means for mounting. The following information shall be furnished on the chart or plate.

Points of application  
Service interval  
Type of lubricant  
Viscosity

3.11 Nameplate. Unless otherwise specified (see 6.2.1), a corrosion resistant metal nameplate shall be securely attached to the machine. The nameplate shall contain the information listed below. If the machine is a special model, the model designation shall include the model of the basic standard machine and a suffix identified in the manufacturer's permanent records. The captions listed may be shortened or abbreviated, provided the entry for each such caption is clear as to its identity.

Nomenclature  
Manufacturer's name  
Manufacturer's serial number  
Manufacturer's model designation  
Class, \_\_\_\_\_ axes pos., \_\_\_\_\_ axes cont.  
Size, \_\_\_\_\_ HP spindle motor  
Style, Tool changer cap., \_\_\_\_\_ tools  
Table travel, \_\_\_\_\_ x axis, \_\_\_\_\_ y axis  
Power input (volts, total amps, phases, frequency)  
Contract Number or Order Number  
National Stock Number, or Plant Equipment Code  
Date of manufacture  
U S

3.12 Technical data. Data shall be furnished as specified (see 6.3).

3.13 Workmanship. Workmanship of the machine and accessories shall be equal to that of the manufacturer's current commercial machines of the type specified herein.

#### 4. QUALITY ASSURANCE PROVISIONS

**4.1 Responsibility for inspection.** Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification when such action is deemed necessary to assure supplies and services conform to prescribed requirements.

**4.2 First article inspection.** When first article approval is required under 3.1, first article inspection shall be performed. Unless otherwise specified (see 6.2.1), first article inspection shall comprise the examination in 4.4 and all tests in 4.5. Failure to pass the examination or any test shall be cause for disapproval of the first article.

**4.3 Quality conformance inspection.** Quality conformance inspection shall be applied to each item prior to being offered for acceptance under the contract. Unless otherwise specified (see 6.2.1), quality conformance inspection shall consist of the examination in 4.4, the tests in 4.5 through 4.5.5, and the inspection in 4.6. Failure of the item to pass any examination or test shall be cause for rejection.

**4.4 Examination.** The machine and equipment shall be examined for compliance with the requirements in 3.2 through 3.5 and 3.8 through 3.13.

**4.5 Tests.** The machine shall be subjected to the following tests. All instruments, tapes, materials, and tools required to perform and evaluate these tests shall be furnished by the supplier. The measuring instruments shall have evidence of calibration traceable to the National Bureau of Standards. The numerical control test tapes and computer printouts used shall become the property of the Government.

**4.5.1 Operational test.** The machine and its numerical control system shall be operated in accordance with the manufacturer's standard operating test procedure for warm-up and run-off checks. During the warm-up period, proper operation of all manual controls, motors, adjustment mechanisms and accessories shall be verified. After warm-up, the machine shall be cycled continuously under numerical tape control for a period of not less than 4 hours. This operation shall include tool change, spindle speed and feed rate (Classes B and C only) changes that include the highest, intermediate, and lowest settings of each range, rapid traverse of all slides, simultaneous



movement of slides and automatic feed cycles as applicable. The numerical control system shall be further tested to verify proper operation of MDI, program edit, and system diagnostics. Should a malfunction occur, it shall be corrected and the operational test repeated until a full 4 hours of running time is completed without failure.

**4.5.2 Alignment and accuracy test.** The machine and its numerical control system shall be tested for conformance with the alignment and accuracy requirements of Table III.

**4.5.2.1 Axis positioning and overshoot tests.** Starting at positions other than the extremes of axis travel, two identical movements of each controllable linear axis shall be programmed and executed in each direction. Programmed span shall be not less than 7 inches, and each digit of starting and end point shall be other than zero with respect to reference zero. Feed rate of axis shall be 2 inches per minute. Absolute positioning and positioning repeatability errors shall not exceed the permissible tolerances of Table III. Similar movements of each linear axis shall be programmed at varied feed rates to test for slide overshoot at accelerated feed rate without programmed deceleration. One pass shall be programmed at feed rates nearest to 10, 20 and 100 percent of maximum linear feed rate. Overshoot shall not exceed 0.003 inch at any feed rate up to 20 percent of the maximum. Maximum overshoot shall not exceed 0.005 inch. Stops shall be programmed appropriately for inspection of control positioning accuracy. Positioning tests may be part of the same tape program as 4.5.1.

**4.5.3 Performance accuracy test.** While using one or more test setups devised by the supplier, the machine shall be tested to verify its ability to perform machining operations under numerical control for meeting the accuracy tolerances of Table II. The test piece(s) may be, at the supplier's option, steel, cast iron or aluminum and the tool(s), spindle speed and feed rate for each test shall be selected by the supplier as the most suitable for the particular operation being performed. The test piece(s) shall present a work surface normal to the tool point and approximately centered with reference to the work area in the xy plane. In milling and contouring test, successive cuts may be made inside the outlines of previous cuts and roughing cuts may be made in the various cuts with excess metal removed as desired to make measurements convenient.

**4.5.3.1 Tapping test.** Pilot drill and tap at programmed locations, four holes each with finished threads to accept 8-32 and 3/4-10 screws. Finished holes shall accept standard 8-32 or 3/4-10 screws freely and threads shall meet Class 3 standards for internal threads as set forth in Handbook H28.

**4.5.3.2 Boring test.** Pilot drill, semi-finish bore, and finish bore not less than 10 holes in a selected pattern covering an area not less than 24 inches in diameter. Four of the holes shall be spaced on 18 inch centers. Different tools shall be used for semi-finish and finish boring operations. All holes may be pilot drilled in sequence, but semi-finish and finish boring of each hole shall be completed with necessary tool changes before beginning boring operations of successive holes. Each address shall be to the fourth decimal place with digits other than zero. Finished hole size shall range from 1.125 to 2.750 inch. The resulting hole location and hole size errors shall not exceed the permissible tolerance of Table II for boring.

**4.5.3.3 Straight-line milling test.** The straight line milling test shall be a programmed square or rectangle, not less than 6 inches per side with sides parallel to the travel along x and y axes. Machines with Class A MCU's shall make this cut at constant z-axis depth of not less than 3/4 inch. Machines with Classes B or C MCU's shall make a plunge cut along one longitudinal side cut. Plunge angle shall be not less than 2 degrees. The resulting cuts shall be checked for dimensional accuracy, squareness, parallelism, flatness, angularity, and corner locations to verify the accuracy required in Table II for straight-line milling.

**4.5.3.4 Circle contouring test.** A circle shall be programmed and milled within the outline of the square cut required in 4.5.3.3. The cut shall be made at constant z axis depth of one-half inch and by using the shortest programming sequence within the capability of the MCU. The resulting cut shall be checked for dimensional accuracy, roundness, surface finish, and angularity to verify the accuracy required in Table II for circle contouring.

**4.5.3.5 Straight-line contouring test.** A square or an equilateral triangle shall be programmed and milled within the circle cut and described by 4.5.3.4 at constant depth of one-half inch. The reference line for one side of the square or triangle shall be 10 to 20 angular degrees canted to the x axis. The resulting cut shall be checked for dimensional accuracy, squareness and angularity to verify the accuracy required in Table II for straight-line contouring.

**4.5.4 Maximum horsepower test.** Using a workpiece of SAE 1020 steel, a straight cut of not less than 12 inches in length shall be made with a face mill or shell end mill. Diameter of the cutter and spindle speed shall be determined by the supplier to be suitable for making the cut with specified chip load and peripheral cutter speeds. The depth of the cut shall be as required to load the spindle motor to its maximum rated horsepower. Chip load shall be  $0.010 \pm 0.002$  and peripheral cutter speed shall not exceed 300 feet per minute. The cutting action shall be smooth and even and the finished workpiece shall show no evidence of tool chatter. In addition, there shall be no evidence of overheating of the spindle drive motor or the applicable feed motor.

**4.5.5 Test program verification.** Unless otherwise specified (see 6.2.1), while using one or more test set-ups devised by the supplier, the machining test program (tape) required under postprocessor validation (see 3.4.10.7.1), shall be run on the machining center to verify its ability to receive and perform all program functions without malfunction or error. The test piece(s) shall be either steel, cast iron, or aluminum, while the tooling shall be selected by the supplier as the most suitable for the particular operation being performed.

**4.5.6 Electromagnetic interference control tests.** Unless otherwise specified (see 6.2.1), equipment requiring electromagnetic interference control testing shall be tested for compliance with 3.8.

**4.6 Packaging inspection.** Packaging shall be inspected to determine compliance with the requirements of Section 5.

## **5. PACKAGING**

**5.1 Preservation, packing, and marking.** Preservation, packing, and marking shall be in accordance with the applicable requirements of MIL-M-18058. The required level of preservation, packing, and any special marking requirements shall be as specified (see 6.2.1).

## **6. NOTES**

**6.1 Intended use.** The numerically controlled machines covered by this specification are intended for use in any production shop where drilling, boring, tapping, reaming, and milling operations by numerical control of the machine are required. The machine may be used to produce prototype parts from a taped process or to produce production items repetitively from a proven process, to accuracies within the capabilities of the machine.

### **6.2 Ordering data.**

**6.2.1 Procurement requirements.** Purchasers should specify their requirements in the procurement documents, including whether each choice is required or not required, by entering an appropriate statement identified to each of the following:

- a. Title, number, and date of this specification.
- b. Class, style, and size required (see 1.2).
- c. First article approval, if required (see 3.1).
- d. Specify additional safety and health requirements (see 3.2.2 and 6.5).

- e. Painting, if different (see 3.3.5).
- f. Threaded parts, if different (see 3.3.6).
- g. Dials, if different (see 3.3.7).
- h. Gears, if different (see 3.3.9).
- i. Hardened and ground guideways for machines supplied with the Class B or C MCUs, if required (see 3.4.3).
- j. Specify the number and configuration of T-slots, if different (see 3.4.4).
- k. Sub-plate and desired characteristics, if required (see 3.4.4).
- l. Specify means of accomplishing z axis movement, if different (see 3.4.5).
- m. Specify special characteristics for spindle noses, bores, if required (see 3.4.5.1).
- n. Coolant system, if different (see 3.4.7).
- o. Specify noise level and enclosure characteristics for stand-alone hydraulic units, if required (see 3.4.8).
- p. Electrical system, electrical supply, and voltage for initial wiring, if different (see 3.4.9).
- q. Electric motor enclosures, if different (see 3.4.9.1).
- r. Feedback devices, if different (see 3.4.10).
- s. Circular interpolation for Class C MCU, specify if the axis that is perpendicular to the selected plane shall not be directed by linear interpolation (see 3.4.10.1.3).
- t. Specify the program selectable (degree) positions required (72 - 360 - 360,000, etc.) and whether the a axis is required to function simultaneously or independently of the x and y axes of motion, if a rotary table is required (see 3.4.10.1.4).
- u. Memory capacity of the MCU, if different (see 3.4.10.2).
- v. Specify characteristics, if bulk memory storage is required (see 3.4.10.2).
- w. Specify fixed cycles, if required (see 3.4.10.2.1).
- x. Specify remote data entry and data source, if required (see 3.4.10.3).
- y. Specify special auxiliary functions, if required (see 3.4.10.3.1).
- z. Tape reader tape reels, if different (see 3.4.10.3.2).
- aa. Data display, CRT or universal readout, if different (see 3.4.10.4).
- bb. Program edit mode, if different (see 3.4.10.4.1).
- cc. Tape punch unit, if required (see 3.4.10.4.2).
- dd. Axis jog, if different (see 3.4.10.5.3).
- ee. Specify the number of tool length and cutter radius compensations, if required (see 3.4.10.5.7).
- ff. Postprocessor, if not required or if different (see 3.4.10.7).
- gg. Specify computer name and model, if a postprocessor is required (see 3.4.10.7).
- hh. Postprocessor validation, if different (see 3.4.10.7.1).
- ii. Standard equipment, if different (see 3.4.11).
- jj. Optional equipment, if required; fully describe (see 3.4.12).
- kk. Electromagnetic interference control, if required (see 3.8).

- ll. Type fungus proofing, if required (see 3.9).
- mm. Lubrication chart, if different (see 3.10).
- nn. Nameplate, if different (see 3.11).
- oo. First article inspection, if different (see 4.2).
- pp. Quality conformance inspection, if different (see 4.3).
- qq. Test program verification, if different (see 4.5.5).
- rr. Electromagnetic interference control test requirements, if different (see 4.5.6).
- ss. Required level of preservation, packing, and special marking requirements (see 5.1).

6.3 Contract data requirements. Required technical data, such as operators manual, parts lists, foundation and anchor bolt plans, wiring diagrams and other instructions for operation and maintenance, as identified on a numbered DD Form 1664, should be specified on a DD Form 1423 incorporated into the contract.

6.4 First article. When first article approval is required under 3.1, it should be tested and approved under the appropriate provisions of 7-104.55 of the Armed Services Procurement Regulation (ASPR). The first article should be a preproduction model or it may be a standard production item from the contractor's current inventory. The Contracting Officer should include specific instructions in all procurement documents regarding arrangements for examinations, test and approval of the first article.

6.5 Safety and health requirements. In order that equipment integrated into the user's operational environment will comply with the Occupational Safety and Health Act of 1970, limitation and control of noise levels, radiation, electromagnetic emission, noxious vapors, heat, etc. as applicable, specific requirements concerning guarding the point(s) of operation, and other safety and health requirements should be specified.

6.6 Mercury prohibited. When the use of mercury or its compounds in the machine and its components and accessories is to be prohibited, procurement documents should include a statement to that effect.

Custodians:  
 Army - AL  
 Navy - SH  
 Air Force - 99

Preparing Activity:  
 DLA - IP

Project Number:  
 3408-0012

Review Activities:  
 Army - AL  
 Navy - SH, AS  
 Air Force - 99  
 DLA - GS

Appendix E

WORK-MIX ANALYSIS

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## Appendix E

### WORK-MIX ANALYSIS

#### 1. Introduction.

Work-Mix Analysis is concerned with the construction and use of a data base that describes the workload in terms of manufacturing parameters, such as physical dimensions, type of machining operations, man-hours for NC and conventional production, lot size, repeat job, etc. The data base is useful as a tool in decision making, but is not a decision making mechanism in itself (like the computation of cost benefit ratios in other areas of engineering). The information collected in the work-mix data base has two basic uses:

- a. It can support procurement decisions for machine tools.
- b. It guides the scheduler in determining whether a part should be made using NC or conventional manufacturing.

Work-Mix Analysis is thus important both for long range planning and for day-to-day operation of the shop.

The initial collection of information for the data base was performed as part of this study with the intent to identify shops in the depot system that can be made more productive through acquisition of NC machines and to determine the machines they should have. To this end all parts that the depot shops have produced during a two month study period (February/March 1979) were evaluated manually. It soon became apparent that the potential benefits from the continuous use of such data are well worth the effort. Based on a projection of the volume of data that will accumulate in the long run, it was decided to computerize the file. The Logistic Systems Support Activity (LSSA, Chambersburg, PA) took care of the computer programming work.

The work-mix data base system is designed to work on a small or medium size computer with disc storage. It is assumed that, initially, each depot will implement the system locally on a computer of its own and that at a later time this will be superseded by one central computer with remote input/output terminals at each depot. A network of data links (with dial up mode operation) will then be needed.

Input and/or deletion of jobs into (from) the data base is organized around a basic layout of four IBM cards. The basic form of output should be hard copy (line printer); soft output (CRT's) in addition to this is desirable. Input card images are processed by a validation program before they are incorporated into the data base. This includes sorting

and checking for compliance with the conventions established in the definition of the various data fields. If invalid data is detected, the invalid card image and the reason for rejection is displayed in the Invalid NC/CAM Input Listing. Valid input is entered into an intermediate file from which it can be transferred into the data base later on.

Updating of the Work-Mix Analysis File (adding, changing, deleting of records) is reported in the NC/CAM Transactions Listing. It is planned that parts shall remain in the disk file for two years after they have been entered or updated. At the end of the two-year period, they will be transferred to microfiche and deleted from the disk. Such updating shall be performed monthly.

Three output reports for the user of the data base are planned:

- a. Work-Mix Analysis File Inquiry. This produces a printout of all the information about one particular part as identified by its drawing number. This kind of inquiry can be performed at any time.
- b. Work-Mix Analysis Summary. This is a monthly report which consists of summaries for various data items such as parts programming time, use of machines by machine ID number, etc. This report is not organized according to individual parts.
- c. Work-Mix Analysis Report. This monthly report will give a printout of the entire file for each drawing number (part). A page of output for each drawing number in the data base (in sequential order of drawing numbers) will be produced. The volume of data in the base may necessitate at some future date to start printing this report less frequently (say quarterly or semi-annually).

## 2. Input Data.

Four different IBM cards with a total of 46 data fields are utilized to input the description of a part into the data base. Twenty-five data fields contain technical information about the job. The others serve as identifiers for drawings, documents, depots, card type, etc.

The first card is the "Nomenclature" card, which supplies a brief narrative description of the part together with drawing number, document identifier code, and Army depot code.

This is followed by the "Identity" card, which contains parts dimensions, the number of tool axes, and other machine features (rotary table, pallet shuttle), type and amount of NC programming time, repeat code, order quantity, work order procurement control number, and the date.



The third card - "Shop Operations Card" details the manufacturing work, this includes machine operations (punching, bending, etc.), machine ID codes, tools, fixtures, set-ups, and the times associated with each activity. One operations card can describe two machining operations. If more than two operations are required, additional shop operations cards can be used.

If the execution of a job has been estimated for both NC and conventional manufacturing, then the information for both approaches should be recorded in the data base. The determination whether the content of a card pertains to NC or to conventional machining is made through the machine ID code of the card.

The last card - "Delete Record" - serves to eliminate a part/drawing from the data base.

Some data elements such as depot code, drawing number, and document identifier appear on all cards and must contain identical information. This makes it possible to update or delete a file entry by means of just one card once a part is in the data base.

### 3. Outputs

a. Work-Mix Analysis Inquiry. A Work-Mix Analysis Inquiry is initiated using a key word ("IMAS"), followed by depot code, drawing number and a requestor code. The output will follow the layout of the file - that is the layouts of input cards 1-3, with the following modifications.

(1) There will be YES/NO print under the headings of round bar stock, rotary table, and pallet shuttle.

(2) Under NC/CV, the printout will read "NC" or "CV". The computer will deduce from the machine identification code which of these applies.

(3) All work orders on record with command code, order quantity, and date will be listed at the end of the printout.

b. Work-Mix Analysis Summary. The intent of the Work-Mix Analysis Summary report is to provide an overview of the workload situation. Documentation of trends in the workload profile is one of the purposes of this report and to this end a figure for the report month is often accompanied by its counterpart for the entire data base (which will cover up to two years). Often averages and cumulative totals are given. The report consists of 8 sections:

(1) Average Lot Size. The cumulative averages for the data base and the report month are provided.

(2) Use of Special Features (Rotary Table, Pallet Shuttle, Round Bar Stock). Utilization of these features is documented according to the number of orders and the number of items produced during the report month. The utilization figures for the entire data base are also shown.

(3) Breakdown of Work by Machine Identifier Code. One line of output is produced for each machine ID code. It begins with the ID code followed by a short verbal explanation of it and the indication of NC or conventional tool. Next, some averages for set-ups and fixture fabrication are given. Finally, the utilization of the machine is shown broken down into seven categories of metal working, (mill/punch, drill/bend, etc.). The percentage of machine utilization as a fraction of the total use of the machine during the report month is given for each.

(4) Repeatability Analysis. The parts produced during the report month and the parts produced during the data base period are broken down according to the percentage that had repeat orders. Printout ranges from "Made Once" to "Made Nine or More Times" in steps of one. The computer deduces all of this information from the repeatability code of the parts, which consists of one decimal digit that is stored in the data base and updated when transactions occur.

(5) Milling Operations. The use of milling is shown broken down according to the number of machine axes. Monthly and cumulative totals of parts produced are given together with their percentage of the total milling work.

(6) Parts Programming Time. Programming time is shown broken down according to the manual, the computer assisted, and the graphics terminal technique.

(7) Dimensional Profiles. Here the feed range that is utilized is shown for the X, Y, and Z axes. This is a tabulation which progresses in interval steps, which are one or two inches wide, and shows the number of orders and the total number of parts for each interval. Figures for the report month and for the entire data base are provided. Total quantities and percentage figures are shown in the form of "Less Than or Equal To" values which accumulate over the intervals of the tabulation.

(8) Breakdown of Work by Command Code. This is a breakdown of the work for the report month managed by Material Readiness Commands. It shows the number of orders and totals for the number of parts, the hours of NC work, and the hours of conventional work.

c. Work-Mix Analysis Report. This monthly report produces one or more pages of output for each drawing in the data base. Each page consists of 5 sections:

(1) Drawing Number Row. This row gives the short narrative description and the drawing number as they appeared on the "Nomenclature" input card together with the monthly and cumulative production quantity.

(2) Part Description Row. This row contains the technical information about the part (X, Y, Z Dimensions; YES/NO Indication Regarding Use of Round Bar Stock, Rotary Table, and Pallet Shuttle; Parts Programming Time) as inputted on the identity card and the current value of the repeat code.

(3) Metal Working Operation. The metal working for the part is broken down into 11 categories (punching, milling, bending, etc.) and the amount of NC and conventional work for each is given. The printout provides for percentage, monthly, and cumulative hours of each. Totals for sheetmetal and machining hours are given.

(4) Breakdown of Work by Machine Identifier Code. One row is printed for each machine used in making the part. The layout of the row is basically that of the corresponding row in the Work-Mix Summary Report (set-ups, fixture fabrication, 7 categories of metal working), with one additional entry "Number of Tools Required". This section of the report is concluded by a row which shows totals for all items in these rows.

(5) Productivity Improvement Ratio (PIR). The productivity improvement ratio is the ratio of manhours needed to make the part conventionally divided by manhours needed to make it with NC tools:

$$PIR = \frac{MANHOURS (CONVENTIONAL)}{MANHOURS (NC)}$$

This ratio can be computed only if data for NC manufacturing and for conventional production of the part are in the data base, otherwise no such output will appear. Further discussion of the productivity improvement ratio appears elsewhere in this report.

#### 4. Application of Work Mix Analysis in Procurement.

The selection of a new machine tool requires decision making at three successive levels, each of which can utilize the data base. They are:

- a. Numerically controlled or conventional machine tool?
- b. Exact type of equipment (e.g. multiple spindle or single spindle lathe, vertical, slanted, or horizontal bed)?
- c. Physical parameters of the equipment (e.g. horsepower, feed ranges, speed ranges).

Initially, an "Analysis Period" must be selected on which the analysis shall be based. All jobs that have been logged into the data base during that period are to be included in the analysis. For the procurement recommendations developed as part of this study, an analysis period of two months (February/March 1979) was used.

a. NC or Conventional Tool? The Productivity Improvement Ratio (PIR) is the key figure for the choice between conventional or NC machines. Our procedure defines it as the ratio of total workhours needed to do a job conventionally over the total workhours to do it with NC.

$$\text{PIR} = \frac{\text{MANHOURS (CONVENTIONAL)}}{\text{MANHOURS (NC)}}$$

The larger the PIR value, the more advantageous is the use of NC machines.

It should be noted that the evaluation of the productivity improvement ratio necessitates that data for both conventional and NC production must be generated for all parts recorded during the analysis period.

After the conventional and the NC work hours for all work recorded during the analysis period are available, the totals of these hours can be used to obtain a PIR Ratio for the Workload Profile. This ratio can then be employed to estimate future manhour savings that will be possible due to the introduction of new NC machines.

If complex parts requiring multi-axis contouring have to be produced, NC production may be the only feasible method, irrespective of cost. For such situations - which are not uncommon in the aerospace industry, but which rarely occur in the Army depots - the above technique is not applicable.

Floor space and floor loading are often given in advance when procurement of new machine tools is considered. The new tools must then be chosen so that they can be accommodated within prescribed limits. NC tools will usually demand less than conventional tools that can handle the same workload.

b. Selection of Equipment Type. The machine-tool market offers a wide variety of machine tools (in the order of 2000 models) among which a selection has to be made. The data base provides a substantial amount of information that will help to narrow the choice down to the desired machine ID code and to identify the desirability of certain special features (rotary table, pallet shuttle). However, there are no formal rules, which can be used to deduce the conclusion from the data. Professional judgment is the key in this decision making step.

A strong interrelation exists between the machine and the cutting tools that can be used on it. The advantages of standardized tools, tool holders, collets, tapers, and fixtures for NC work have been pointed out elsewhere in this report. Once such standards have been established they will influence the selection of new machine types.

c. Specification of Equipment Parameters. The cost of machine tools tends to increase with the rated values of their parameters (feed ranges, spindle speeds, horsepower, etc.). The increase in cost is sharper for NC than for conventional machine tools. It is, therefore, usually uneconomical to select a NC machine such that it can handle the part with the most extreme demands. Our analysis procedure assumes that conventional machines, which could be used, will be available. This is a reasonable assumption for the depots, since to date they are overwhelmingly equipped with conventional machines and most of the parts are sufficiently simple to be made conventionally.

After the initial decision in favor of NC has been made and the equipment type has been selected, the workload profile must be reviewed to obtain values for the machine parameters. Cumulative plots for the most significant parameters (such as the dimensional profiles for the "x", "y", and "z" axis in section 7 of the Work-Mix Analysis Summary Report) are used to select values such that the bulk of the work can be handled. One might, for instance, choose values such that 85% - 90% of the parts in the workload profile can be made by the new NC machine. The remaining parameters of the new tool must then be chosen such that they will be fully adequate for these parts.

##### 5. Application of Work Mix Analysis in Day-to-Day Operations.

The need to choose between the use of NC and conventional tools is ever present once a shop is equipped with both kinds of machines. The decision in favor of NC will be immediate if the data base reveals that a part has previously been made by NC, so that a NC tape which has been tested and used is already in existence. If this is not the case, a (cost) comparison for the two approaches is appropriate. Work-Mix Analysis offers two tools for this:

a. Checklists for the detection of promising NC candidates. A part should be considered a promising candidate for NC manufacturing, if it and its conventional production exhibit one or more of the characteristics below:

- (1) Short run of a complicated part.
- (2) High labor costs as compared to material cost.
- (3) High cost tooling and low volume.

- (4) Shop produces many similar parts (all in small quantities).
- (5) Set-up constitutes large part of total labor.
- (6) Many operations and set-ups.

This list is an adaption of the list developed by John Moorehead for use in the Work-Mix Study Procedure of the Air Force\* to the needs of the job scheduler.

b. Computation of break-even quantities (Break-even Points). The relative effort necessary to manufacture parts conventionally or with NC is highly dependent on the lot size. Typically NC will require a larger amount of preparatory work prior to the production of the first item (because of parts programming), but subsequently the cost per part at the machine tool will be lower. The total cost for either method will grow approximately linearly with the lot size. In a plot (see Figure E-1) the costs for the manufacturing techniques appear as two straight lines which intersect at the break-even point. For quantities larger than the break-even quantity NC production is the cheaper method. The determination of the break-even point often turns out to be a dramatic argument in favor of NC. Generally, break-even occurs for much smaller quantities than anticipated by those unfamiliar with NC. Many industrial consultants blame the (incorrect) expectation that one will need at least medium size lots (50 to 100 parts) to break-even for the sluggish acceptance of NC in the manufacturing community. By contrast: The study team computed the break-even point for a sample of six randomly selected parts (out of the material collected in connection with this study) and found a break-even quantity of less than 10 in each instance.

## 6. Discussion

a. The Work-Mix Profile generated for procurement purposes is that of the analysis period. Its use is reasonable only to the extent to which the profile forecasts future requirements correctly. It cannot indicate features, which would be desirable to meet objectives outside of the workload of the analysis period, such as readiness requirements or increased interchangeability of work between facilities.

b. The Productivity Improvement Ratio of our procedure is a modification of the "Productivity Ratio" used by Childs\*. He defines the

\*"Use of Numerically Controlled Equipment Can Increase Productivity in Defense Plants," Appendix I, pp. 59-72. Report to Congress by the Comptroller General, 1975

\*AFLCR 66-50, 22 February 1978

productivity ratio as machining hours (conventional): machining hours (NC). His ratio is concerned with the production throughput of a conventional tool as compared with a NC tool and not directly with cost. The study team reasoned that the labor costs will be the biggest cost factor for either method of production. It was, therefore, decided to define the Productivity Improvement Ratio simply as the ratio of the manhours for the two methods of production:

$$\text{PIR} = \frac{\text{MANHOURS (CONVENTIONAL)}}{\text{MANHOURS (NC)}}$$

The PIR is a crude indicator of relative cost which is easy to compute. It excludes consideration of the cost of the machine tools and their amortization. The use of total manhours corresponds to the practice of the Army to use an average hourly cost, which does not reflect the type of work, in labor cost projections. There are considerable differences in education and training of personnel for the two manufacturing methods. It is to be expected that personnel costs for NC as compared to conventional shops will be somewhat higher than is indicated by the PIR.

c. The initial input for the data base at each depot will be the information for the months of February and March 1979 which was collected and analyzed as part of this study. The data was originally collected and punched into cards in a format that differs from that described in the report. The Directorate for Management Information Systems (D/MIS - in Sacramento) is writing a one-time computer program to convert the study data into the new data base format.

d. The input to the data base will often consist of estimates. They should be replaced by the values actually experienced in production whenever possible. It is not known how close the estimates produced by experienced personnel will come to the actual production data. The data base, as it is presently laid out, does not contain indicators with the data elements which would distinguish estimates from observed values. Such a distinction should be introduced later on, if the operation of the data base shows that it is warranted.

e. The entire data base was conceived and developed as a part of this study. It is a rather complex endeavor, we expect that experience in its use will soon lead to a variety of improvements.

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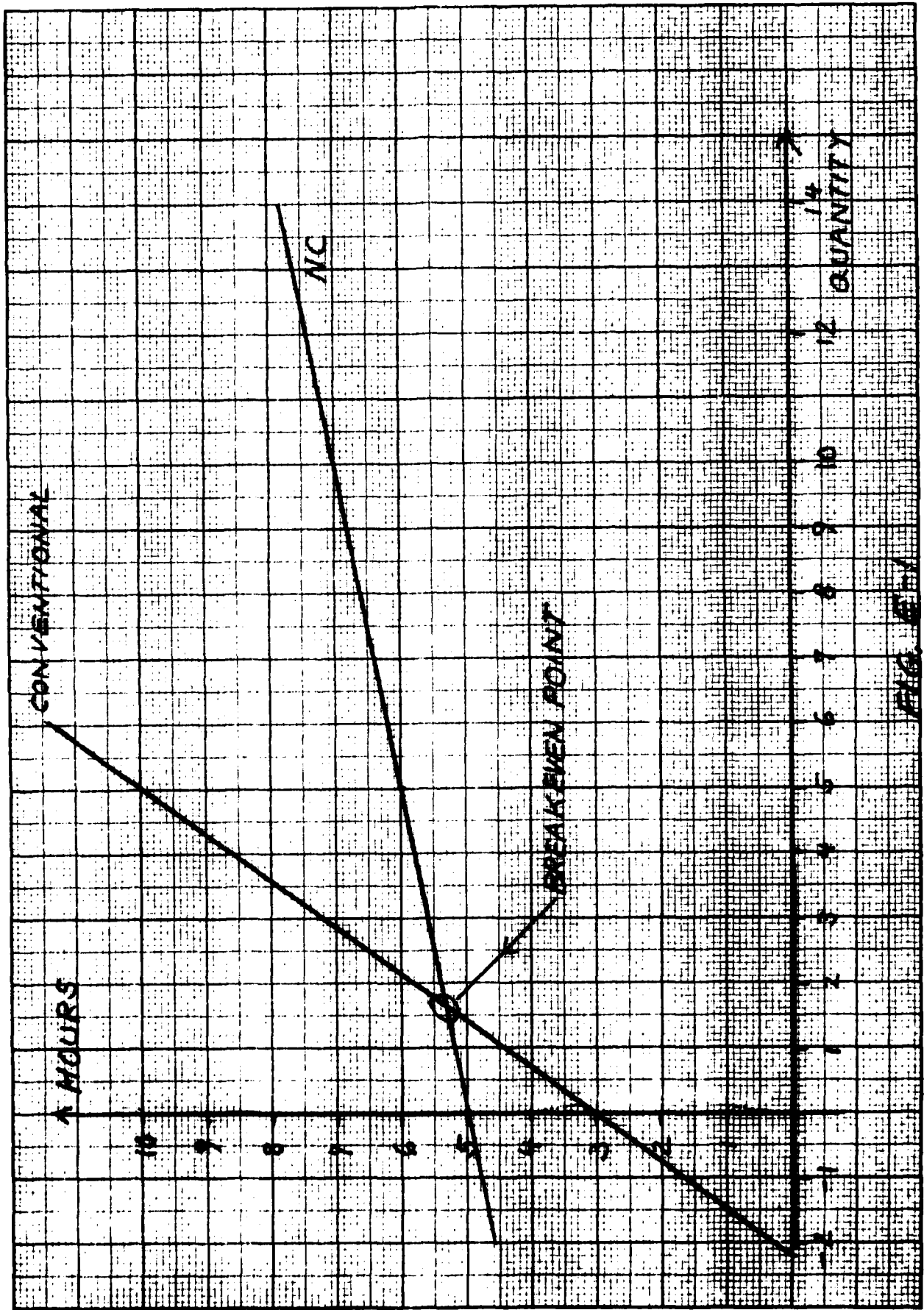


FIG. 8-1

Appendix F

DAY-TO-DAY OPERATION

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## APPENDIX F

### DAY-TO-DAY OPERATION

#### 1. Introduction.

The adoption of NC will produce several visible and a number of crucial but not so visible changes in the manufacturing plant. The obvious differences which even the casual visitor will notice are in the various personnel categories (particularly the split between white collar and blue collar staff) and in the relative floor space requirements of functional departments within the plant, such as the white collar activities of design, drafting, storage of drawings, NC tapes, parts programming, tape storage, computers, computerized storage and the blue collar areas of raw materials, tools and fixtures, shop floor and inventory of parts for off-the-shelf delivery to customers. In a typical NC facility, the white collar share of personnel and floor space is higher than it would be in a comparable conventional plant. Some less obvious changes occur in plant coordination and in record keeping. The machine tools on the shop floor are both more costly and potentially more productive than conventional tools. Correspondingly more effort has to be made to maintain a smooth flow of work through the machines. This demands increased attention to preventive maintenance, work scheduling and care in record keeping.

Digital computer technology has changed tremendously since the 1950's when the concept of numerically controlled machines was introduced. Today its presence is felt beyond the batch type processing of parts programs in the form of "softwired" control of many devices including machine tools and in the presence of data bases, i.e., the computerization of record keeping. Many problems that used to be typical headaches of computer center personnel are now encountered in manufacturing plants, for example:

a. "What you don't see is what you get." This phrase was originally coined by people involved in purchasing computers. It is meant to express that more and more of the money spent is for software and also to indicate that the value of a system to its user is, to a considerable degree, determined by the quality of its software. As computerization of manufacturing progresses, this remark becomes increasingly applicable to it.

b. GIGO ("Garbage In - Garbage Out"). Many computer users have learned the hard way that the output from a computer tends to be no better than the input data. The remark is applicable to all information storage connected with NC, and the importance of conscientious record keeping cannot be overemphasized.

## 2. Effect on the organization.

a. **The Work Force.** With the advent of NC, several new jobs have appeared in the manufacturing world. The duties and the number of people needed in some existing job-categories have changed. Some new kinds of jobs are computer programmer for software maintenance, parts programmers, keypunch operators and (additional) file clerks. The machinist on the shop floor has changed from a true "machine operator" into somebody who might more adequately be termed "machine supervisor." The machines should be making chips a considerably larger fraction of the time and, therefore, the same volume of production is accomplished by a considerably smaller number of machinists. The demand for precision in tool fabrication is increased, but the tool volume is somewhat lower due to less breakage. The volume of fixture fabrication should be substantially lower. The number of service technicians for a given volume of production will probably be about the same. However, they should be more highly skilled, and if the shop is well managed, they will spend more of their time doing preventive maintenance and less time responding to actual breakdowns than they would with conventional machines. In summary: For the same volume of production the number of white collar jobs goes up somewhat and blue collar jobs decrease sharply when NC is introduced.

The amount of NC machinery that the depot system will acquire between now and the end of FY 1983 - if the recommendations of this study are followed -- is quite small in relation to the inventory of conventional machines. It is too small to have a numerically significant impact on the size and composition of the technical workforce.

Systemwide the number of machine tools (see Appendix H for details) will develop as follows:

	YEAR		
	1979	1983 PROJECTED	CHANGE
NC	31	76	+45
Conventional	1406	1348	-58
Total	1437	1424	-13

The primary effects of the proposed acquisitions will be an improvement in the manufacturing capacity and the readiness posture of the system. An increase of 8 to 10% in the overall manufacturing capacity, with concentration in areas which are presently bottle-necks, can be hoped for.

The table projects growth of the percentage of NC tools from 2.15% to 5.33% (which is somewhat below the 6% figure, that is

presently typical of commercial manufacturing in the U.S.). Correspondingly, one can anticipate that the percentage of the manufacturing workforce that needs to be familiar with NC will grow from above 2% to between 5 and 6%. There is no reason to fear that any present employee will lose his job due to the introduction of NC tools. Approximately one technically oriented blue collar worker out of every thirty presently employed in the system will have to become part of the NC workforce. It should be possible to find the necessary combination of intelligence, reliability and willingness to learn in such a fraction of the present personnel. At present there is a keen demand for NC personnel in private industry. Retainment of those who have qualified themselves for NC work in the depot system might well become a problem unless adequate steps are taken to provide equitable job classification, and challenges.

The representatives of labor organizations are sometimes fearful of new manufacturing technologies. They reason that productivity improvements will lead to the elimination of some jobs presently held by their members. It should be clear from the numbers in the above discussion that such fears are not warranted in connection with the modernization plans for the depots described in this study. This needs to be made known to the employee organizations as early as possible.

A common attitude towards technical innovation that is shared throughout organized labor does not exist. The organizations that represent technical employees differ from depot to depot. The management/labor dialogue with regard to NC will have to take place at the local level.

In traditional accounting, blue collar work is considered "direct labor" whereas white collar activities appear as "overhead." The separation of costs into direct labor and overhead in this way is not workable in manufacturing with NC machines. The reduction of blue collar work and the (modest) increase in white collar work would combine to produce a very sharp rise in overhead. However, high overhead is customarily considered a sign of poor management and plant managers are under pressure to hold overhead costs down. The traditional accounting approach thus tends to discourage the use of NC machines in spite of the reduction in overall cost that is feasible. Many government contracts are written to contain fixed overhead percentages, which cannot be met if NC machines and traditional accounting are used.

Accounting procedures for production with NC machines should draw the line between direct labor and overhead in a new way: Activities like parts-programming, keypunching and record keeping, which are

without decision making power over either product design or plant operations, should be classified as direct labor costs.

b. Floorspace. A typical NC machine might turn out to occupy twice as much floor space as its conventional counterpart and manufacture four times as many parts/hour. For the same volume of production the necessary amount of shop floor will generally decrease as NC machines are substituted for conventional ones.

An unused NC machine is a bigger loss than a conventional machine that goes idle. To avoid work stoppage due to lack of raw material for an NC machine, one should plan on having a larger stock of raw materials than one would in a comparable conventional operation. The area for raw materials storage should, therefore, be larger.

The higher productivity of the NC machine requires that raw materials be supplied to it at a higher rate than to a conventional tool. This needs to be considered when the location of the NC machine, vis-a-vis the supply area, and the conventional machine tools is determined.

Production of parts which are repeat orders on NC machines requires less leadtime than would be needed with conventional machines. Some commercial enterprises have found that they can provide the same level of service with substantially smaller inventories if they equip their shop with NC. Thus, warehousing floor space for finished parts should decrease. The savings that are possible in this area depend on the amount of repeat orders that occur.

The introduction of NC demands floor space in the office for tape preparation, tape storage and keeping of (computerized) files. The floor area devoted to drafting can be reduced at the same time if a graphics system for parts programming, design and storage is adopted. Unless this is done, the floor space needed in the white collar areas will increase when NC is introduced.

c. Plant coordination. The machine tools on the shop floor are both more costly and potentially more productive than conventional tools. Correspondingly, more effort has to be made to maintain a smooth flow of work through the machines.

Since it is so essential to keep the NC machines working continuously, extra managerial effort is indicated. It must be concerned with all things that could impede production:

(1) The machine must be kept in shape. Preventive maintenance - which costs time according to its predetermined schedule and not on the basis of surprise - is a must.

(2) The personnel - operator and maintenance men - must be well trained and back-up should be available on short notice.

(3) The arrival of "production inputs" (raw material, NC tapes, tools, fixtures and measuring devices) and possibly supervisor or parts programmer at the machine should all be carefully coordinated by advance planning. The assumption has to be that the operator will not "go to get things" but will stay glued to the machine.

(4) The production inputs delivered to the machine must be painstakingly kept reliable. This places high demands on the conscientiousness of those concerned with recordkeeping of various kinds. Most crucial is probably the management of NC tape storage. First of all, it must be possible to find existing tapes quickly. Identification of tapes should, as a minimum, provide drawing number and date of NC tape manufacture. The date is important because at times there will exist several tapes for the same job. CNC machines offer the possibility to edit and duplicate tapes on the shop floor. This versatility will become a curse if it results in the creation of a "family of tapes" for a part without thorough documentation of the differences between these tapes. Some commercial plants have found it necessary to clamp down vigorously on the proliferation of tapes. One company does it as follows: they have a master file of Mylar tapes in the parts programmer's office. The office makes a paper tape copy which is sent to the shop each time a part is to be remanufactured. Shop personnel are under strict orders to immediately destroy all paper tapes after they have been used.

(5) Quality control. The inspection of finished parts of NC production requires concentration on the first item in the batch. Once the first item is known to be satisfactory, subsequent ones can be trusted to be faithful duplicates without those variations that the human operator inadvertently introduces during conventional machining. Thus, control inspections after dimensions and tolerances have been found adequate for the first item can be mostly restricted to concern with possible defects of materials. Techniques which try to take advantage of fluctuation in a parameter during manufacturing, like the search for matching parts, have no application in NC production.

### 3. Maintenance.

The investment and the productivity potential associated with NC machines is high. A maintenance strategy that minimizes downtime is, therefore, essential. One must be willing to make allocations which seem

high in comparison to those for conventional equipment in the areas of maintenance personnel, preventive maintenance, test instrumentation and possibly spare parts stocking.

a. Inhouse or by contract? NC maintenance people are highly trained individuals with very specialized skills, who must keep their cool under pressure (as they will typically be after a breakdown has occurred). These factors and also the similarities in trouble shooting tools and diagnosing techniques invite comparison to the maintenance of digital computers. One question which such a comparison will immediately provoke is: Should one not choose to depend on a maintenance contract (with the equipment manufacturer) as is so often done for large digital computers? The study team probed into this possibility and found: No, one should not! The major considerations that lead to this conclusion are:

(1) Supplier of machine tools and control units are usually not able to maintain the level of service (response time to trouble calls) that is available for large digital computer systems. This is so because the investment in even a complex machine tool is smaller than that in a large computer system and the number of identical units in the field is usually much smaller.

(2) The number of different manufacturers who have equipment in a machine shop is typically much larger than the number of manufacturers having equipment in a computer center. It is usually impossible to cover all NC maintenance needs by a single contract.

(3) Machine tools contain a large number of moving mechanical parts. They must meet heavy mechanical and thermal demands in an unconditioned, dirty environment. The intervals between routine preventive maintenance activities are shorter than those for digital computer equipment.

(4) The useful life expectancy of a machine tool is much higher than that of present day computers which are often superseded by a new improved machine only a few years after installation. The cost of establishing in-house maintenance capability for NC machines has a considerably longer period of time to repay itself.

(5) Maintenance personnel should be part of the team that decides new machine-tool acquisitions. Their knowledge about critical reliability aspects of proposed new acquisitions is usually better than anyone else's and the good will created by their early involvement is likely to pay high dividends. The participation of maintenance personnel in the acquisition process should further mean that all maintenance requirements of a proposed acquisition will be fully comprehended and the



necessary equipment secured. A new machine tool like other complex equipment will have a break-in period during which its maintenance needs are higher than later on. Consequently, it is important that maintenance training (at the vendors plant) be completed before the new machine is put into service.

b. Preventive Maintenance (PM). Manufacturers will supply schedules of preventive maintenance operations (once/shift, once/week, once/month) which should initially be followed to the letter. After experience with a machine has been gained, it may be possible to make some adjustment which reflects the local environment to these schedules. Written records of all maintenance actions should be kept.

Preventive Maintenance occupies time that is lost for production. However, one should not try to cut corners here. Downtime will almost certainly increase as PM time is reduced.

c. Test Instrumentation. Faster component response (considerably smaller rise times), lower voltage levels, higher output impedances and increased susceptibility to noise in electronic circuits have combined to make the instrumentation for circuit-level testing in contemporary electronics considerably more expensive than that used 20 to 30 years ago. Very often special purpose instruments obtained from the equipment manufacturer are appropriate for tasks corresponding to those once handled with a multimeter (Volt-Ohm-Milliammeter) and at most a basic oscilloscope with clip leads.

Integrated circuits reduce the connections accessible for test purposes to those directly associated with the external pins of a package. Functional testing as opposed to circuit testing assumes more and more importance as chip complexity increases. This means that digital input sequences, which have been prepared (and stored) in advance will be applied. The reaction of the system to these inputs is then compared to the expected behavior. Once again special purpose equipment is often used for functional tests and is expensive.

The introduction of microprocessors into the control unit is a blessing from the viewpoint of maintenance. To begin with, it means increased use of error protection features such as parity bits in the hardware itself. Next, the memory and the data-processing capabilities of CNC controllers can be used to run sophisticated diagnostic routines. Such testing will utilize the normal input and output devices of the controller. It is, therefore, easy and quick, and the potential that mistakes of the personnel will harm the equipment is not there.

The microprocessor in the control unit has the potential for continuous monitoring of a large number of variables in the machine tool.

It seems that this potential is not yet fully utilized at present. Progress in this area will probably occur soon and it will increase the need for maintenance personnel to be at ease with computer hardware and computer software.

d. Spare Parts. Quick response to a machine breakdown is usually only possible if the replacement parts that are needed have previously been stored in easy reach of the NC machine. The acquisition of parts from outside the plant after the breakdown has occurred will always take too much time (considering parts availability, shipping delays and, most importantly, purchasing red tape). To know what parts one should stock requires mortality data for the various parts in the machine and its controls. At the time of a machine purchase the manufacturer's knowledge in this respect is vastly superior to that of his customer. It is, therefore, recommended that initially the manufacturer's kit should be purchased, even if it seems expensive (say up to 20% of the basic machine tool cost). Later on modification of the spare parts inventory based on actual maintenance experience should be made.

A centralized spare parts inventory for the depot system has been considered by the study team and was rejected as economically not sound. This conclusion is mainly based on three considerations:

(1) Savings from centralized spare parts stocking are feasible only if the depot system has several identical machines in different depots. This is not likely to happen very often.

(2) The cost of the downtime that elapses while the arrival of a spare is being awaited (say 2 -- 3 days) will usually be higher than the value of the spare part itself.

(3) Obtaining spares from any source other than the shelves in the local maintenance department means time consuming red tape. The maintenance procedure needs to be such that one can fix the machine first and do the paperwork afterwards.

Some general considerations regarding failure rates for components of NC machines are:

(1) Electromechanical devices (tape-reader, relays, etc.) are usually the most failure prone parts. A spare tapereader for an expensive NC machine may well be justified.

(2) The reliability of electronic devices did generally improve when vacuum tubes were replaced by discrete transistors. It improved again substantially when discrete transistors were superseded by integrated circuits.

(3) CNC controllers have a smaller number of (more standard) components than older controllers. This should mean a smaller spare parts inventory and better reliability than can be had with any of the older controller technologies.

#### 4. NC Utilization.

a. Commercial Practices. Many commercial manufacturers keep their NC equipment working for two or even three shifts (i.e., around the clock). The primary motivation for this is cost efficiency.

The investment in NC machines is high and the cost of operator time in relation to the volume of items produced is small (when compared to conventional production). It is, therefore, economically advantageous to produce irrespective of added wage costs for nightshifts. Heavy utilization of NC machines helps to amortize the machines quickly and to wear them out before they become obsolete. Finally, operation around the clock, in which the power is never turned off, leads to fewer breakdowns of the machine. This is so because the wear of many parts is mainly due to changes in their state (warming-up, cooling-down, electrical transients, etc).

During operation one must try to keep the chipmaking time as high as possible. This depends on parts programming, shop coordination and maintenance practices as discussed elsewhere in this report.

b. DoD Considerations. Cost effectiveness is a valid goal for all manufacturing facilities. In the Army Depot system it is, however, accompanied by additional requirements. The readiness posture of the military services demands that a considerable surge capacity for national emergencies should exist.

One can assume that under emergency conditions NC machines will be used 24 hours per day. Consequently, NC staffing in the depots must continually be at such levels that around the clock operation is feasible. Personnel must be sufficient to staff at least two shifts independent of each other. During a national emergency, overtime can then be used to cover the third shift, i.e., personnel will have to work two 12-hour shifts.

A capacity reserve exists only if the machines are not normally used around the clock. A reserve equal to 100% of the normal workload is possible only if ordinarily the machines are used for, at most, 12 hours per day.

The most practical way to satisfy readiness requirements is probably to plan on using NC machines normally for only one shift, but always have enough personnel trained in NC to staff two full shifts.

c. Utilization Records. Record keeping as prescribed in DARCOM Regulations 700-82 and 700-7 is not fully sufficient for NC machines. DARCOM Regulation 700-7 "Installation Equipment Management - Automated Systems (IMES)" states that runtime, downtime and maintenance time shall be monitored. The optimal scheduling of the flow of raw materials, tools, fixtures, tapes, etc., through the machine, and the scheduling of maintenance, personnel, etc., can be aided considerably by more detailed use records. Further, many of the entries in the workmix analysis data base (e.g., runtimes, setup times) can only be unverified estimates unless collection of utilization records is undertaken to support them. The study team proposes, therefore, that the items listed below shall be monitored. Some quantities of interest (Category A) are observable on the machine, others will be known by the operator (Category B) or by his supervisor (Category C).

**CATEGORY A:**

- A1) Power on
- A2) Tape Moving
- A3) Spindle Turning
- A4) Chipmaking

**CATEGORY B:**

- B1) Setup
- B2) (Preventive) Maintenance
- B3) No Tools, Fixtures
- B4) No Raw Material
- B5) No Tape
- B6) Other

**CATEGORY C:**

- C1) No Operator
- C2) Machine Breakdown
- C3) Power Failure
- C4) Other

There are basically three methods for recording which can apply here:

- 1) Manually
- 2) Time Meters with Manual Actuation
- 3) Automatic Data Collection by Devices on the Machine

The study team proposes that record keeping for Category "C" should be done manually by the supervisor or the NC coordinator. He should be required to keep a Log (book) and record disruptions of operation together with their time of occurrence (begin and end).

Record keeping for Category "B" should be the responsibility of the machine operator. It is suggested that in the startup phase of an NC operation, the time (begin and end) of each activity be recorded. After the NC operation has been phased in, it may be sufficient to collect elapsed time. These records can be prepared manually or preferably (for convenience of the operator) by an automatic device with manual inputs. The U.S. Airforce (AFLC San Antonio, ALC KAFB Tex, AF Code Identification Number 98750) has developed an "NC utilization recording device circuit," which can be used here. This device consists basically of six time meters, any one of which can be chosen manually through a six-position selector switch. In new CNC machines, the collection of these records may be implemented as a function of the control unit. A microprocessor must then provide the timing circuits which the operator activates and deactivates from the manual data input keyboard.

For the quantities in Category "A," it will be sufficient to obtain elapsed time over some length of time (say for an entire job lot, once per shift or weekly). Manual recording (even if it takes nothing more than setting a switch or pressing a key) would put an undue burden on the operator and slow down production. The collection of these data should be fully automated. The quantities of interest can be detected by sensors which provide input to a microprocessor system.

Future specifications for new NC machines will have to spell out how the collection of utilization records in Categories "A" and "B" is to be accomplished.

#### 5. Post Analysis.

a. DoD Requirements. Funding for machine tool acquisitions can presently come from three different programs:

- (1) Quick Return on Investment Program (QRIP).
- (2) Production Base Support Program (PBSP).
- (3) Procurement Authority (PA)/Other Procurement Authority (OPA).

The first two of these funding channels include a requirement for a comparative before/after study. Only PA/OPA funding includes no such procedural requirement. For QRIP projects, "audit trails on costs and savings (dollars and manpower)" are required (in AR 5-4). The PBS Program, as outlined in AR 700-90 and DA Pam 700-23, calls for the initial justification on a "Machine Tool Replacement Analysis Worksheet," (DD Form 1106), which compares the costs of operating the existing equipment and the proposed new equipment respectively for the anticipated workload

of the first year after installation of the new equipment. The comparison consists of an "operating cost analysis for equivalent output," which is mostly concerned with the cost of personnel, maintenance, power, scrap and tooling and a "capital cost analysis." At a later date (usually after the first year of operation of the new equipment) a "post analysis report" (DD Form 1651), which checks the operating cost analysis forecast of the DD Form 1106 against actual experience, has to be completed.

The existing postanalysis procedures appear to be unpopular with depot personnel. During the visitation of depots, members of the study team were repeatedly told by employees that postanalyses are unproductive and the need to perform them was questioned. It can further be observed that some factors, such as shop flow and staffing inadequacies, which have considerable bearing on the success of NC operations, are not part of the postanalysis under those previously established guidelines. The study team, therefore, proposes a different postanalysis procedure for use with newly introduced NC machines.

b. Proposed postanalysis procedure. At the end of the first year of operation of an NC machine, a post analysis consisting of three parts shall be performed:

- (1) The manhour savings projected prior to the acquisition shall be compared to actual values.
- (2) The occurrence of unintentional downtime shall be analyzed.
- (3) Work stoppages due to lack of supplies at the machine shall be analyzed.

The actual manhour savings (as compared to conventional machining) shall be computed based on the total number of machining hours during the year and the productivity improvement ratio of the workload profile of the machine at the end of the year. The total machining hours can be obtained by summing the figures from the monthly "work-mix summary reports" of the work-mix analysis data base (see Appendix E). The productivity improvement ratio at the end of the report year shall be based on an analysis of the actual workload during the last one-month period of the report year. (A different study month shall be used if the load during the last month is known to have been atypical. A written explanation of this shall be furnished.) To obtain the productivity improvement ratio for the study month, the manhours for both NC and conventional manufacturing for each job during this month have to be computed. The PIR of the workload profile is then the ratio of the totals of these quantities, i.e.,

$$\text{PIR} = \frac{\text{TOTAL CONVENTIONAL HOURS}}{\text{TOTAL NC HOURS}}$$

The product of this PIR and the total machining hours shall be used to compute manhour savings. These manhour savings shall be compared with the prediction made in the procurement justification. If the post-analysis finding differs from the figure used for procurement by more than a factor of two, the reasons for this difference shall be analyzed in writing.

Unintentional downtime shall be evaluated for the last six months of the report year. The records kept by the supervisor (category C of the utilization records in this appendix) shall be summarized. The ratio of total unintentional downtime to total production time shall be computed. If this downtime ratio is smaller than 0.05, the situation shall be considered normal and nothing further needs to be reported. For downtime ratios greater than 0.05, a written analysis of the reasons for downtime shall be made. It shall, as a minimum, investigate whether improvements might result from changes in spare parts inventory or preventive maintenance practices.

Undesired work stoppages shall be evaluated for the last six months of the report year. The records kept by the machine operators (category B of the utilization records in this Appendix) shall be summarized. The ratio of total unintentional stoppage (items B3, B4 and B5) to the total production time shall be computed and recorded. If this stop-time ratio is smaller than 0.05, the situation shall be considered as acceptable and nothing further needs to be reported. For stop-time ratios greater than 0.05, a written analysis of shop flow with improvement recommendations shall be prepared.

The NC coordinator shall be responsible for the preparation of post-analysis reports.

#### c. Discussion.

(1) The proposed postanalysis procedure tries to assess not only the workload and the technical performance of the machine but also the working environment and its impact on the productivity of the machine. The evaluation of numerical factors, which shed some light on the quality of the shopflow and of maintenance procedures in addition to the reliability of the machine, gives them usefulness for the future. This will hopefully reduce the feeling that postanalysis is irrelevant for what goes on in the plant.

(2) The use of numerical values which indicate the limits of what is considered acceptable (factor of 2 for the manhour savings,

ratios of 0.05 for the downtime ratio and stoptime ratio) and the call for additional reporting and analysis only if the limit value has been exceeded is based on the concept of exemption reporting. It should eliminate unnecessary analysis work when conditions are satisfactory, and thus, in a way reward "good behavior."

The selection of the limit values has posed some difficulty. Only for the downtime ratio did we find publications which indicate that the value 0.05 has been attained and often considerably surpassed in private industry. The critical value of 2.0 for manhour savings comparison and of 0.05 for the stop time ratio are proposed for initial use in our new method of postanalysis. They are suggested critical values which we offer without support from published literature or in-house experience. They should be reviewed and possibly changed as soon as enough pertinent field data have been accumulated.

(3) The numbers that will be generated and possibly discussed during our postanalysis are all based on events which have occurred.

(4) Some weaknesses of the procedure required in the PBS program (DD Forms 1106 and 1651) are the large number of estimates for conditions which were not experienced and the differences in the magnitude of the contribution that come from the factors that are considered. Further, there exist, at least for NC machines, some factors which have a larger effect and are not included. Examples: the cost of the electrical power for any machine tool is very small compared to personnel costs. Inclusion of estimated power costs in an analysis that also uses estimated personnel costs for a machine that "might have been" used is hardly worth the effort. Computing the value of the scrap that would have materialized on machines that might have been used should similarly produce a small value but is very difficult to do. Members of the study team tried unsuccessfully to obtain experience values for it from the literature or from depot employees. The relationship between necessary inventories, production leadtimes, and total costs is not considered in any existing cost/benefit analysis procedure. For NC machines, it has probably considerably more impact on the total costs than any of the abovementioned factors.

(5) The study team believes that the manhour savings figure obtained in part 1 of our postanalysis procedure is adequate for use in cost avoidance, cost reduction and savings reports.



Appendix G

SKILLS AND TRAINING

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## Appendix G

### SKILLS AND TRAINING

#### 1. Introduction.

Salaries and wages constitute the overwhelming part of manufacturing costs. Numerical control is economically attractive because it entails a drastic reduction in manhours. The capabilities demanded from the personnel during the remaining manhours are quite different from those needed in conventional machining. The losses that may result from shortcomings of the personnel are often considerably higher for NC machines. For instance, consider an NC machine and a corresponding conventional machine, which are each unnecessarily down for a day because your maintenance people failed to diagnose a problem correctly. The loss in production on the NC machine will be several times (say 5 times higher) because it is so much more productive when it works. Increased attention to staffing and training is an absolute prerequisite for successful NC operation.

The knowledge needed in the NC field encompasses a body of basic knowledge (such as digital electronics, tape codes, control theory and servomechanisms, parts programming and computer programming) and information about the machines and control units of specific vendors. Efficient and thorough training will separate these two aspects of instruction.

The general basic topics can be, have been, and should continue to be taught in courses of the Army Management and Training Activity (AMETA). Possibly AMETA should expand the amount of NC training that is offered by correspondence. AMETA's courses alone should be adequate for managerial level personnel and for parts programmers, who program simple parts in the APT language. Parts programmers for machine specific parts programming languages and shop personnel should be given a basic course by AMETA and thereafter be trained by the vendors. Vendors will often conduct training of machine operators at the site where a machine tool is being installed. Programming and maintenance trainees will commonly be sent to the supplier's plant.

The temptation to hold monetary costs of training to a bare minimum is great when budgets are tight. But insufficient training of NC personnel will almost certainly prove a forbiddingly expensive way to go. The best and most expensive NC machines will not do a better job than the people working with them. The state of the art, particularly in computerized numerical control (CNC) is changing rapidly. The possibility to modify the behavior of a machine tool through changes in the operating software implies the need for retraining NC personnel as

such changes are made. Ongoing training efforts to keep personnel abreast of innovations will become more important in the future than they were in the past.

Estimates of the number of personnel, that will be needed by the depots to cover the general facets of NC work are tabulated in Figure G-1. These data were collected from participants at the In-Progress Review Conference of this study in Corpus Christi and have been furnished to AMETA.

## **2. Parts Programmer.**

The level of education and experience needed for parts programming depends primarily on the complexity of the part to be programmed. The language in which the parts program has to be written is only of secondary importance\*. Figure G-2 depicts the findings of an inquiry by the Numerical Control Society into the relation between part complexity and the knowledge needed by the part programmer.

One similarity between general computer programming in a high level language (Fortran, Algol, Pascal, etc.) and parts programming should be noted: The time needed to learn the rules of a language through classroom instruction is quite short. The time one must practice programming to learn to skillfully use them is much longer. Classroom training for a parts programmer will absorb from one to three weeks. The time on-the-job before an individual reaches his full capability will be an additional 3 months to 1-1/2 years thereafter.

The bulk of the NC programs for use in the Army Depots, just as elsewhere, can be classified as "simple". In view of this, and of the increase in educational prerequisites that goes with programming for complex jobs, it makes sense to distinguish two classes of parts programmers:

a. Programmers for simple applications (point-to-point machining and up to 2-1/2 axis contouring). They should have a good machine shop background. In addition to this, they need to be creative and not too set in their ways. Their mathematical preparation should include trigonometry and the use of cartesian and cylindrical coordinate systems. Blueprint reading is a must.

b. Programmers for 4 and 5 axis contouring machines. They need a full college-level math background such as can be expected from people with degrees in Computer Science, Engineering or Mathematics. Since such people will usually not possess shop experience it should be planned that

\*"Numerical Control Language Evaluation" R&D Technical Report,  
ECOM-0058-F, 31 March 1974

they will work together with a person with an extensive shop background. The study has found little need for machines with more than 3 axis in the depot system. Training for such machines should remain separate from courses offered by AMETA and be arranged on an individual basis if the need arises.

A publication of the Numerical Control Society\*\* in 1977 reports the following findings from a survey which investigated NC use as a function of the size of manufacturing plants:

Number & Percentage of Responses	Plant Size (Number of "Direct Labor" Employees)	N u m b e r o f NC Machines	Conventional Machines	Average Number of Parts Programmers
40 18%	1 - 49	4	32	1.9
38 17%	50 - 99	6	48	2.2
44 17%	100 - 199	7	73	2.4
56 26%	200 - 499	7	137	2.6
19 9%	500 - 999	9	90	3.4
21 10%	1000+	20	557	5.5

The survey results indicate that industry employs approximately one fulltime parts programmer for every three NC machines it has. The average lot size and the frequency of reuse of control tapes in the depot system will probably be lower than in private industry. If this is the case, a larger number of parts programmers will be needed.

The Numerical Control Society has recently introduced a program for NC programmer certification. A programmer can be certified under one of three categories of proficiency. The categories reflect workpiece complexity: Category 1 certification indicates good capability to program simple parts; Category 2 corresponds similarly to parts of medium complexity, and Category 3 is for complex multiaxis contouring work. The depots should rarely need programmers with the abilities attested to by certification in Category 3.

\*\*"Numerical Control Coordinator" by NC Coordinators Committee of NCS  
NC/CAM Journal, February 1977

### **3. Electronic and Mechanical Maintenance.**

The transition from conventional to NC tools leads to some increase in the necessary number of maintenance personnel and to a sharp increase in the abilities required. Smith and Evans\* give the following estimates of maintenance personnel requirements:

- a. For simple NC machines 0.1 - 0.2 technicians/machine
- b. For complex (Aerospace type) NC machines 1/2 electronic and 1/2 mechanical technician/machine.

A summary of the capabilities maintenance personnel must have appears below:

#### **MAINTENANCE SKILLS**

- \* Ability to work from complex blueprints, sketches, hydraulic system schematics and manufacturers manuals.
- \* Ability to apply binary mathematics to NC machine functions.
- \* Ability to use precision measuring devices, dial indicators, micrometers, precision levels, optical measuring devices, and laser light devices.
- \* Extensive knowledge of electrically and electronically controlled mechanisms, complex high pressure hydraulic systems, tape reading control mechanisms, Servos.
- \* Understand and read tape language.
- \* Ability to use electronic test equipment - audio oscillators, logic probes, interferometer, voltmeters, capacitance - resistance analyzers.
- \* Extensive knowledge in operation of all machine tools.

### **4. NC Operators.**

Operating an NC machine requires less skill but sometimes more knowledge than working with a conventional machine. The main duties of

\*Management Standards for Computer and Numerical Control by Donald N. Smith & Lary Evans, Institute of Science & Technology, University of Michigan 1977.

the operator are loading, unloading and checking of tools and fixtures and of parts being produced. He must be able to read engineering drawings, check tools, possibly adjust cutter compensation or tool offset features on the machine control unit and take precise measurements. Many machines are equipped with "manual overrides", e.g., for feedrates; the operator must know how to use these intelligently. Some experience in operating a similar conventional machine is probably the best possible preparation for this.

Contemporary NC machines are for monitoring purposes equipped with readout devices that range from digital readouts to CRT displays. Correct interpretation on the display demands that the operator be familiar with the codes used on the control tapes. The introduction of CNC has considerably increased the volume and complexity of the information that can be displayed at the machine. A corresponding increase in knowledge by the operator is needed to make use of this. The task that is probably the most demanding assignment an operator faces is the first run of a new tape (it is desirable to have the NC programmer do this if possible). A great deal of NC operator training in the past has occurred "on-the-job".

#### 5. NC-Coordinator.

The NC Coordinator is the jack-of-all-trades for the NC field. A publication of the NC/CAM Journal\* contains the following list of duties and functions:

- Evangelism
- Consulting Services
- Training
- Long Range Planning
- N/C Organizational Structure
- Job Description
- Evaluation and Hiring
- NC Software Management
- Tool Description and Selection
- Monitor Downtime
- NC Utilization
- NC Tape Preparation
- Machine Tool Plans thru Installation
- Internal Research and Development

The appreciation of this listing is aided by a statement made at a meeting of the NC Coordinators Committee of NCS and the reaction it provoked:

\*"Numerical Control Coordinator" by NC Coordinators Committee of NCS  
NC/CAM Journal, February 1977

"We are all looking for a man who is a super salesman; a dedicated evangelist; has a degree in Mech. Eng.; a degree in Electrical Engineering; was a Business Administration major; has a complete working knowledge of investment economics; an understanding of cash flow; an intimate knowledge of the total manufacturing process; preferably with 5 years of Journeyman experience on the shop floor; has a good grasp of data processing technology; and finally is an expert in NC technology." He then added, "If anyone knows where I can find such a man I'd like to hire him." A few seconds of stunned silence followed this statement while everyone got his feet back on the ground. It was at this point that the group realized the NCC might be anything from a part time individual to a full organization."

The reader should infer from this that a competent NC Coordinator is vital for the success of an NC operation and also that a concise job description, which is the standard of the industry has not evolved to date.

This is further highlighted by the survey findings about the background of people employed as NC coordinators:

#### EDUCATION

College Degree	36%
Some College	31%
Vocational School	51%

#### EXPERIENCE

Shop Experience	81%
NC Programming	83%

#### CAPABILITIES

NC Machine Language Progr.	90%
Computer Assisted NC Progr.	82%
Computer Programming	46%
Mechanical Maintenance	40%
Electronic Maintenance	20%

The ability to deal with people is probably the single most important asset an NC coordinator must have. A great deal of salesmanship will be demanded of him when NC machines are first introduced. The survey results quoted earlier (see under 'Parts Programmers') indicate that throughout industries which utilize NC machines, such machines still constitute only about 6% of all machines in use. Insufficient attention to the human side of the introduction of new technologies is probably the reason why this percentage is so low.

## **6. Other Considerations.**

A small but increasingly important facet of NC installations is software maintenance. Formerly, this was solely concerned with occasional updating of the parts programming language processors and post-processors. The introduction of "softwired" CNC machines and intelligent terminals expands the possibilities for future improvement through changes in the operating software considerably. At present, the maintenance of such software is usually performed by the supplier of the original software package.

The compensation paid to various categories of NC personnel in the three services was the subject of a study by the Air Force in 1976.\* They found a considerable variation in pay for comparable work between installations and recommended that DoD-wide pay schedules for NC work should be established. To the best of our knowledge this has not been implemented yet.

\*Study of Personnel Resources Associated with Numerically Controlled Machine Tools in the Department of Defense Draft by U.S. Air Force 1976



QUANTITATIVE TRAINING ESTIMATES  
Furnished to AMETA

C O U R S E	D E P O T N E E D S							TOTAL
	ANAD	CCAD	LEAD	NCAD	PUDA	READ	SAAD	
A. NC Orientation Top/Middle Mgrs	5	4	5	3	3	20	10	63
B. NC Parts Programming (APt)	4	4	4	1	1	3	5	26
C. Maintenance - Mechanical/Electrical	4	5	4	5	1	6	5	41
D. NC Copordinator	2	1	1	2	1	2	1	12
E. NC Operator	6	10	5	5	1	6	5	45
F. CAM For Engineers	2	3	4	1	1	4	8	25
G. NC Advanced Mgmt	2	3	3	3	1	3	2	19

FIGURE G-1

EDUCATIONAL REQUIREMENTS	PART COMPLEXITY								
	Point-to-point and straight cuts ( $2\frac{1}{2}$ axis)	Non-formula defined curves	Repetitive cuts and family of parts	Curves and straight lines ( $2\frac{1}{2}$ axis)	Controlled rotary motion	Inclined planes and patterns	Sculptured surfaces	Swarf cut, formula defined and regular surfaces	Multi-axis, including 5 simultaneous motions
Basic Machining Practices	*	*	*	*	*	*	*	*	*
Plane Geometry		*	*	*	*	*	*	*	*
Simple Algebra		*	*	*	*	*	*	*	*
Simple Analytical Geometry			*	*	*	*	*	*	*
Solid Geometry				*	*	*	*	*	*
Algebra					*	*	*	*	*
Analytic Geometry						*	*	*	*
Basic Computer Programming (desirable)							*	*	*
Descriptive Geometry								*	*
Plane Trigonometry								*	*
Spherical Trigonometry									*
Digital Computation									*
Numerical Analysis									*

FIGURE G-2

**APPENDIX H**  
**OVERALL CONCEPTS**

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## OVERALL CONCEPTS

### 1. INTRODUCTION -- CAM.

The computer in manufacturing today is accelerating and receiving worldwide promotion. The Fourth International Conference & Exposition on Programming Research and Operations Logistics in Advanced Manufacturing Technology (PROLAMAT) was held in May 1979 at the University of Michigan with over 50 papers from Brazil, England, France, GDR, GFR, Hungary, Japan, Netherlands, Saudi Arabia, United States, and USSR. The proven and potential benefits of the computer in manufacturing are so evident and the technology is advancing so rapidly that evidence of a second Industrial Revolution is in the making.

The magnitude of the benefits of this computer application and integration technology has opened up the door to significant Government funding of large study programs. Some of these are: CAM I, (Computer Aided Manufacturing International); ICAM, (Integrated Computer Aided Manufacturing), a ten year, \$75 million US Air Force Program; NASA's IPAP, (Integrated Program for Aerospace Vehicle Design), and CASA, (Computer and Automated Systems Association) by the Society of Manufacturing Engineers; and CAPP, (Computer Automated Process Planning). CAM-I and CAPP are reviewed subsequently.

The applications of computers, both the large-frame types and the small specialized minicomputer types, are being introduced at an accelerated rate into all areas of parts and equipment design, manufacture and control. Computers are now functioning at all levels of manufacturing -- from the actual design of components to the control of production processes. Furthermore, there are already a number of successful programs by various companies towards completely integrated computerized systems that join many operations together into a hierarchy on a real-time basis. These moves are the forerunners of the automated integrated factory or manufacturing facility. Such an application of computer technology combined with manufacturing technology has resulted in the rapid growth of the new field of Computer Aided Manufacturing (CAM). Similarly, when computer technology is applied to the design of parts, assemblies or systems, the result is Computer Aided Design (CAD). CAD is covered in the following section.

Forecasts based upon in-depth studies show that by 1982, CAM techniques will be available for controlling and processing certain groups of parts automatically, and better and simpler dedicated computers will be available for smaller facilities or plant operations. By 1985, software systems will be available which will, e.g., accurately predict optimum work-mix, or manufacturing costs based upon part definition only. In addition, assembly operations will be integrated with other

manufacturing operations to create cost-effective CAM systems. Computerized management information systems will be commonplace and the majority of machined or processed parts will be designed using computer graphics. By 1988, it is predicted that the production of an item will be automated to the point that 80% of the required processes will heavily involve the computer.

The evolution of such a total CAM system will probably start with many small minicomputers dedicated to specific tasks (accounting, shipping, etc.) and will be grouped to an interacting larger intermediate computer. The intermediate computer will control various processes such as inventory, tooling, planning, quality control, etc. A final stage will be a hierarchy level in which a large fast computer with enormous storage will interact with the intermediate computers. Such a total CAM system is shown in Fig. H-1. Any part of the system affecting the manufacturing efficiency, Return on Investment (ROI), delivery, or whatever, would alert the proper responsible individual or department. Writing the software of such a complex system would certainly have to be a long-range procedure.

All of this raises the question of how the Army Depots fit these particular predictions.

Before reviewing the status of CAM for the various depots of DESCOM, a basis for comparison is presented for planning and recommendations, thus an explicit definition of CAM has to be given along with a partial list of the numerous management and manufacturing functions, where a computer is, or can be, applied. This list also provides another valuable input by pointing out the computer applications a depot could beneficially utilize, and if they can be incorporated into their maintenance programs.

It is apparent that nearly any use of a computer in the manufacturing process can justifiably be designated as CAM. History shows that early applications of CAM to manufacturing were as follows:

- (1) Cost evaluation of design.
- (2) Cost estimating of manufacture.
- (3) Inventory control.
- (4) Production control.
- (5) Quality control.
- (6) Start at standardization.

- (7) Bill of materials.
- (8) Master scheduling and planning.
- (9) Order, release and control.
- (10) Process and routing.
- (11) Shop order release.
- (12) Scheduling and dispatch.
- (13) Production reporting.
- (14) Capacity.

Subsequently, CAM has been widely extended in its applications and gradually refined. CAM later included manufacturing processes that involved Numerically Controlled (NC) machining, followed by DNC and CNC.

One major extension of CAM relates to the CAM "system" (as distinguished from single CAM application) as a manufacturing system in which the computer is used as an integral component. A hybrid example is the Computer Numerical Control (CNC) machine which has a minicomputer as an integral part of the total machine.

The depots, as with different entities, have manufacturing charters that differ considerably. Following as a natural consequence, the meaning of CAM will also differ with different individuals as with their various depots. What is required to provide a basis for a CAM system is a general model stating as nearly as possible all of the functions involved. Such a model should be made all inclusive so that a viable application for a particular depot will not be overlooked. The listing of such functions can only be supplied after each depot has committed itself to CAM and a careful assessment is made of feasible applications of CAM. As a point of information, a few depots are already active in the use of CAM. The model for a CAM system should certainly include the following functions:

- (1) Initial information.
  - (a) Design considerations and specifications.
  - (b) Availability of the same, or similar part, or drawing of the part at a depot in DESCOM.
  - (c) Required completion date, quality, disposition of parts.

(2) Manufacturing activities involved at a depot by these functions.

(a) Planning and Scheduling -- make-or-buy decisions, material requirements, special tooling, test equipments, manpower, etc.

(b) Manufacturing -- machining, processing, assembly, testing, etc.

(c) Controlling -- production, quality, costs, inventory, delivery, etc.

(3) Administration

(a) Personnel policies.

(b) Finance.

(c) Management.

(d) Other rules and regulations.

There comes to mind other activities which could be included in the above model of functions for a depot, however, the ones presented cover the main functions involved in the depot maintenance process. Now, if any depot uses computers, or computer technology for these functions in a coordinated or unified sense, the result is truly a CAM system. One can find many examples where the computerization is partial, but the emphasis or movement is towards total computer involvement. The fundamental ingredient for a CAM system is that it be organized to function as a part of the system. The application of the computer or computer technology cannot be haphazard, but should be so planned and coordinated that the application is natural and easily accepted and executed. A following section reviews a survey of CAM for the various depots.

A comparison, between the old conventional method of manufacturing without the aid of the computer and with CAM, is essential to show the merits of CAM. The major differences are in the way the communication is handled and the information is processed. In a conventional system, information is disseminated verbally, or by notes and letters; the latter method requires the slow process of handwriting the letters and scheduling a secretary for typing. Also, manual record keeping in a variety of usually mysterious formats is employed where most decisions resulting therefrom are made after a long involved process of assembling and analyzing the data. Standardizing the procedures, though attempted, is compromised by the interpretation of the person handling the data. More advantageously, a CAM system with the aid of computer hardware and software assembles, organizes and analyzes the data involved in the manufacture of a part. A computer program is carefully assembled and

yields data based upon a standard or accepted procedure. The flow of information can be readily checked thus preventing expensive errors. Within the manufacturing constraints, routine decisions can be made automatically. Many departments are involved in the manufacturing process. CAM provides a focal point for rapid and accurate interfacing of the various functions listed in the general model.

Nearly all the computer-oriented companies are actively engaged in marketing various aspects of CAM or CAD. One company, for example, offers any manufacturing facility a comprehensive, real-time system for controlling all phases of production, from the receiving dock through final assembly. It provides current accurate data on product structures, engineering changes, cost, material requirements, inventory status, material movement, and capacity.

Using data entry directly through video display work stations at the point of origin, this system monitors every phase of the manufacturing process. Every time a part is pulled from stores -- every time an order is released from the shop -- the system updates all affected records, identifies component sources, and performs any other required inventory analysis and material management operations. All reports-- whether from engineering, the shop, management, or production -- are served from the same base of accurate, up-to-date information.

All data can be accessed on demand, as printed reports or on the video display stations, which places information immediately at the hands of authorized personnel.

There are a number of special offshoots of CAM such as Group Technology (GT) which deals with the similarity in the design and manufacture of discrete parts. MICLASS is one such special program that utilizes a coding system to reduce the need of new design of parts. A family-of-parts concept is the foundation for this system. There remains a question of how these special techniques fit into CAM and the depot picture. In short, they are special forms of CAM. These and other variations of CAM are reviewed later.

## **2. CAM STATUS OF DESCOM.**

CAM is found to be interrelated with the use of numerically controlled machinery and results in NC/CAM. Thus, computer technology is a vital part of modern manufacturing methods. In a similar fashion there is also DNC/CAM, or CAD/CAM. Certainly NC/CAD/CAM is a present reality, however, the shorter acronym NC/CAM usually implies a total system concept including design, manufacture and management through the use of computers. With this somewhat clarification of terms, an important part of the study is a survey to determine the present status or extent of NC/CAM in DESCOM. This was initiated first by a request by the DARCOM



Computer Aided Manufacturing Steering Group (1978) to identify CAM (or more distinctly NC/CAM) facilities, equipment and software at each depot, and address the following questions:

- a. Describe the CAM facilities, equipment, and software at your installation.
- b. Describe the additional unfunded CAM equipment and facilities needed.
- c. Describe recently completed local efforts which contributed to CAM technology development.
- d. Describe currently funded efforts locally sponsored which contribute to CAM technology development.
- e. Describe additional unfunded CAM technology development efforts that would benefit the command, installation or activity.
- f. Identify machine tools planned for next five years. Give types, quantity, estimated costs, and planned year of acquisition.

A following breakdown dealing primarily with NC machinery was requested by the NC Study Group for the following:

- a. Quantity of NC machines currently in use.
- b. Identify each by manufacturer and model, include type of control unit.
- c. Identify year each was acquired.
- d. Cost of each machine.
- e. Give quantity of machine tools presently in use and total value.
- f. Describe the state-of-the-art of CAM at your principle contractor.

The answers to the above questions on the NC/CAM status at the various depots were successfully completed and indicates that by far the bulk of the information collected dealt with the number, kinds and costs of NC machine tools at each location. The survey dealing with CAM is premature at this stage for making statements for comprehensive NC/CAM systems for the depots. CAM is just receiving the proper impetus and advertisement to get potential applications uncovered. In contrast, NC machine tools have been around for a long time and the depot users are far more familiar with their applications, whereas utilization of computers for aiding in the management and manufacturing process is

essentially in a first-phase or introductory stage for the depots. This assessment is strengthened by observing Fig. H-2, DESCOM Present and Projected NC and Conventional Machine Tool Requirements, which shows NC machinery has definitely been included in different degrees in planning and acquisition activities as compared to the minimal efforts on CAM. Fig. H-3, Types of NC Machines in Present DESCOM Inventory, is a companion to Fig. H-2 and gives supplementary information on the types of NC machines, e.g., lathes, drills, etc., in the present DESCOM inventory.

A more definitive breakdown of NC/CAM shows that within DESCOM there are only seven depots that have NC Equipment (NCE). These include Anniston Army Depot (ANAD)(quantity of 3 NCE), Corpus Christi Army Depot (CCAD)(quantity of 9 NCE), Mainz Army Depot (MZAD)(quantity of 3 NCE), Sacramento Army Depot (SAAD)(quantity of 3 NCE), Tobyhanna Army Depot (TOAD)(quantity of 6 NCE), Tooele Army Depot (TEAD)(quantity of 5 NCE), Savannah Army Depot Activity (SADA)(quantity of 2 NCE). In total, there are currently 31 pieces of NCE within DESCOM (valued at \$3.3 million), and only one interactive graphics design system located at CCAD.

The history of the studies on NC/CAM for the depots shows one such study conducted by TEAD in 1966. A three-year implementation plan recommended the acquisition of four NCE. The first machine was received and installed in November 1966, and the remaining three NCE were obtained in 1967. In 1968, a follow-on study to determine if continued modernization of their 175 conventional machine tools was necessary. Recommended was a vertical mill, an NC lathe, an NC 3-axis milling, drilling and boring machine, and a 60-ton NC punch press. Due to unknown problems, the NC lathe was not procured although it was justified in 1966, 1968 and other years since. In 1977, another modernization study conducted by the US Army Industrial Base Engineering Activity, Rock Island, IL recommended the acquisition of an NC lathe, an NC horizontal 3-axis milling, drilling and boring machine, and a 60-ton 2-axis NC punch press. This confirmed the previous study recommendations. The NC lathe was subsequently acquired as excess from Lexington-Blue Grass Army Depot.

The next study was conducted at CCAD in 1968 and 1969, by the US Army Production Equipment Agency (PEQA) which resulted in the acquisition of an NC milling, drilling and boring machine, and two NC lathes. Five additional NC machines have since been acquired. In 1970, a Cordax measurement and inspection machine was acquired which can be categorized as a CAM activity. In 1971, the interactive graphics design system was acquired which provided CCAD with a CAD capability.

NC/CAM studies have been conducted at SAAD since 1969, but continuous delays have prevented the acquisition of any NCE until 1978, when an NC punch press was transferred from Lexington-Blue Grass Army Depot. It, however, was incomplete, necessitating almost a complete rebuild with assistance from the manufacturer.

Relating to CAM activities, there are no computer time-sharing terminals in any installation to date except for CCAD, therefore, very little computer-assisted part programming has been established at the depots. There are, however, three CNC machine tools in the system. There was an NC programming terminal requested by TOAD for FY 78, but it has not yet been approved or funded. SAAD requested in FY 78 an A/D computer for programming of additional NC machines.

The information in Figs. H-2 and H-3 clearly presents the DESCOM status on NC machinery, whereas the CAM activities are not unified and are limited to a few depots. The number of NC machines is to increase from 31 to 76 units by FY 83 as shown by Fig. H-2, Part 3, and with an approximate reduction of 58 conventional machines. This trend is in the right direction but should be increased.

To amplify on the potentials of CAM, the history of CAM for the Rock Island Arsenal (RIA) of DARCOM is recommended for review since it points out possible directions that can be taken by DESCOM. RIA installed its first NC machine tool in 1958. In-house computer support came in 1966. The same year the Arsenal Operations Directorate (AOD) installed an automatic CAM data system. Seventy-five terminals located in nine buildings were used to transmit production and labor information to a Control Data 106A which generated production status and labor efficiency reports. The same computer system did the Arsenal's cost accounting and customer billing. The major advantages were maintaining time schedules and key punch savings which resulted from the direct use of collected data.

In 1973, RIA initiated a program called Pilot Automated Shop Loading and Control System (PASLACS) which has promise of improving the Production and Control (P&IC) program. A commercial software program was installed on the local IBM 360-65 computer which increased the productivity of RIA's direct labor force. Cost and production lead times were reduced for all of RIA's products. PASLACS involved material requirement planning, capacity requirement planning, input/output control and dispatching.

Additional CAM by RIA that would be beneficial but has not yet been funded are:

- a. CAM for developing labor standards -- productivity, work scheduling, staffing requirements, etc.
- b. Computer assisted process planning. (There is no present effort in this area. A present program CAPP deals with this subject and is discussed later.)
- c. CAM for the selection of equipment -- a decision process.

d. CAM for optimum process planning. Involve material flow in shops, operations, etc.

e. Adaptive control (see Intelligent Hardware Section).

### 3. SPECIAL CAM APPLICATIONS.

One special branch of CAM that is receiving rapid acclaim in industry is Group Technology.

Group Technology is a manufacturing process or concept which recognizes that similarities occur in the design and manufacture of discrete parts. The general tendency is to consider each manufactured part as being unique. A closer observation of the part population reveals many commonalities, parts can be categorized into groups or families if the fundamental designs are identified. GT programs are therefore designed to replace the tedious and costly manual procedures of designing and providing information for parts which have generally similar configurations. GT accomplishes this with systematic interacting computerized systems which have a data base on design and manufacturing on all previously configured parts.

All of the Services are very active in GT. The Navy is installing a Manufacturing Data Systems, Inc. (MDSI) code system at the Naval Ordnance Laboratory in Louisville, Kentucky, and the Air Force has just completed an in-depth study of the numerous domestic and foreign GT systems.

The United States Army Armament Research and Development Command (ARRADCOM) has recently procured one of the available GT systems called MICLASS and implementation is now in progress. The contract for this proprietary system provides that the system, including the software, will be made available to all departments of the Army installations at no cost except for training.

A symposium was held by ARRADCOM in 1978 to bring together leaders in CAM and CAD at the Army Depots and SUBCOMS to explore the cost effectiveness of the MICLASS GT system. A tour was made of the Otis Engineering Company, Carrollton, TX where MICLASS has been successfully introduced into the manufacture of machine parts for the oil drilling industry.

Some of the highlights of MICLASS are reviewed so as to supply basic information for its possible use by the depots.

a. MICLASS can do the following:

- (1) Serve both design and manufacturing needs.

(2) Make it easier to retrieve drawings, cut design duplication down to an absolute minimum.

(3) Standardize drawings and material uses.

(4) Increase efficiency of CAM.

(5) Generate process plans, information on manufacturing set-ups, machine tool selection, jigs and fixtures.

(6) Give management the information to optimize product mix, analyze manufacturing operations and machine tooling investments, and layout machine shops in more cost effective ways.

b. MICLASS is a computer program not requiring special skills for your own computer to do the following:

(1) Classify parts by their engineering and manufacturing characteristics.

(2) Establish a data base for design and manufacturing information.

(3) Establish retrieval programs for drawings, route sheets, manufacturing instructions, etc.

(4) Analyze programs which are used for design standardization, optimization of machine tool use and manufacturing routines.

MICLASS works conversationally. The computer asks questions and the user types in the answers. Everything is in simple English so that the system can be used by anyone in the depot.

The implementation of MICLASS is done by two studies by the outside vendor: (1) to determine whether or not MICLASS would benefit the depot and (2) to identify specific areas where it can be used to maximum advantage. Full-scale implementation involves the training of depot personnel in coding and analysis, the classification of parts, the creation of company analysis files, and training in the analysis procedures which lead to design standardization, standardization process plans, and the installation of a Computer-Aided Process Planning (CAPP) system.

Another special CAM system, CAM-I Automated Process Planning Systems (also a CAPP system) is being announced as a new concept in manufacturing and closely resembles RIA's PASLACS program. Again, a review of the fundamentals of this system provides inputs to present and future CAM programs by DESCOM.

CAPP is a prototype computer program developed to assist those individuals and organizations whose responsibility is to produce manufacturing process plans for the formation of parts. There are four basic purposes for the development of a CAPP system:

1. To allow examination of the feasibility and utility of computer-assisted process planning. (This enables the user to determine the benefits to be derived and program enhancement possibilities.)

2. To provide a base for future applications. (Common external interfaces can be defined, information and data structures normalized, and man/computer interaction evaluated.)

3. To direct the immediate needs of process planning across broad lines, e.g., between the depots. (This would include the centralization of master planning, source data, maintaining currency and integrity of plans, the reduction of manual clerical staff, and skill improvement for process planning.)

4. To provide a common manufacturing base for process planning. (Process planning is the heart of information for manufacturing. Strengthening the manufacturing process planning function would help in bridging the gap between engineering and fabrication information sources.)

CAPP provides the means of reducing the individual skill and experience necessary for a process planner to function productively. It is a way for standardizing and optimizing production methods by removing vacillating decisions found with individuals.

CAPP provides storing master sources of previous plans in on-line computer storage, thereby eliminating the filing of numerous hard copy masters.

CAPP should have a major impact on all manufacturing organizations. The standardization alone is expected to reduce the cost of manufacturing as much as 20-30% without a change in current resources and funding.

Out of the accelerating number of applications of CAM, one more is worthy of notation, since it involves the merging field of robotics. (See Section 8 on Robotics.) Most of the technology required to employ industrial robots in CAM and CAD already exists.

General Motors has been using a system called SIGHT which is a seeing computer. Looking through electronic cameras, computer programs sense, interpret, and analyze visual scenes. They can inspect parts, serve as robot "eyes," and can reliably perform difficult assembly live tasks while shunning off hazardous environments.

SIGHT II, a GT system, is now in developmental stages. This system will analyze parts, compute its geometric properties, form a model, and commit the model to memory. It then finds similar parts by matching their characteristics with those of the stored model.

#### 4. CAM AND COMPUTERS.

Computers are the center of all CAM programs. Nearly all depots have a large-scale computer of some kind, such as the IBM 360, and certainly a number of minicomputers of the PDP-11 variety. The introduction of CAM into a depot mission would certainly require an inventory of the computers available, and whether or not they have time available on a time-sharing basis for the inclusion of CAM or derivatives such as MICLASS, CAPP, or other GT type programs. A limited amount of information was collected by this study on the various computers at the depots, their dedication to inventory, cost accounting, personnel data, NC, CAM, and other programs. Since the acquisition of such computer information was not part of the NC Study objectives, these data are, at best, limited. If CAM is to become a viable part of a "readiness" goal, a concerted effort will need to be made in the compilation and analysis of such computer data and how they can be phased into CAM programs for the depots.

Some of the problems that will have to be addressed in the integration of computers into the manufacturing process are: interface, software integration, software maintenance, and data base maintenance. Of course, the smaller the manufacturing facility, the less serious will be these problems, however, large integrated systems such as being developed by the Air Force (ICAM) will be the first to recognize their full magnitude. The use of standards on software and communications interfaces appears to be a viable way of integrating CAM systems with a minimum of conflict and future complications.

#### 5. CAD.

Computer Aided Design (CAD) was earlier defined as applying the powerful techniques of computer technology to the design of parts, assemblies or systems. In many application areas CAD and CAM are closely related since the computer jointly aids both the design and the manufacture of a machine part.

CAD, as it is known today, is primarily, but not necessarily, the integration of a computer and a TV-type viewing screen, or CRT monitor. For the design of parts, a typewriter keyboard is available to the user (engineer, manager, scheduler, etc.) whereby essentially a conversational procedure is established between the user and the computer. This procedure is properly labeled Interactive Graphics. The computer program is quite extensive providing the designer with a wide selection of

instructions in the design of parts. CAD involves the use of so-called intelligent hardware, thus, the applications of interactive graphics were thoroughly covered in Section C. Some aspects of interactive graphics are now reiterated along with additional information to round out the picture.

The user can design a simple or complex three-dimensional part and observe each separate line, circle or arc on the monitor as it would evolve on a drawing board with the aid of manual drafting tools. The design can easily be modified in process, furthermore, the designer is motivated and aided by questions and appropriate answers posed by the computer. Consequently, parts can be designed from conception to a total design by the interactive graphics system.

Consider further that the interactive graphics system provides complete English/metric dimensions, standard drawing views, isometric views, and exploded views all almost instantly and automatically. At any time in the process of designing a part, an 8½ x 11-in. hard copy can be made in a few minutes for future reference. After the part is designed, an attached plotter can generate any size standard print (A to E sizes or larger) to full military specifications.

Even more importantly, the computer, interactively with the designer, generates an optimal cutter path for the selected machine to cut the part. Finally, with the appropriate postprocessor program for the NC machine to be used, a cutter tape is generated with a single entry on the keyboard. Computer automated graphics, whether applied to the design or production function, is a proven, indispensable aid to the major operating departments in modern installations. CAD is thus an integration of applied mathematics, computer science and proven console procedures with a three-dimensional graphics system.

CAD offers improvements in quality, lead time, and costs. These are the goals when a department considers implementation of such a system. Opportunities exist in every depot to simplify and improve graphics and automation. Automation of the following jobs has been successfully applied with interactive graphics:

- a. Drafting.
- b. Design.
- c. Engineering documentation -- bar and pie charts, data plots (linear, logarithmic, etc.), maps.
- d. Structural analysis.
- e. Packaging analysis.



- f. Modeling solids.
- g. Integrated building design.
- h. Decision processes.

Computer graphics technology is finding increasing application in a variety of fields. It was found in the survey that many CAD systems are in use today, ranging from relatively simple inexpensive ones to highly complex expensive installations. It is important to note, the prices of all are dropping dramatically while their capabilities are becoming more sophisticated, with their impact on the design and manufacturing entities increasingly evident. Costs were covered partly in the section, Intelligent Hardware.

The aircraft companies are rapidly obsoleting their drafting departments and installing multiply-connected interactive graphics systems. The reason is evident. Consider a case, for example, where a draftsman requires 50 hours to produce a finished drawing of a complex part working from a rough sketch. With the same sketch and with an automated system, the finished drawing took only two hours. Such savings cannot be ignored. Even a smaller operation, a two-terminal Interactive Design System (IDS) will provide cost-effective stand-alone design and drafting capability for a depot for entire engineering design and documentation requirements. Even in a depot with a very limited, or no, design activity, charts, plans, etc. are a vital part of the total mission requirement, thus justifying the acquisition of an IDS.

What are some of the other important particulars of an IDS that would be valuable for a depot consideration and acceptance?

a. An IDS is a software-oriented system incorporating a Central Processing Unit (CPU) with minicomputer and random access disk memory providing both data management processing capability for a number of minicomputer-controlled graphics terminals.

b. A terminal is a user/computer interface and is of the "intelligent" type. The computer performs an intelligence function from proper commands keyed in by the designer.

c. A large number of terminal configurations are offered by the vendors of graphics systems -- starter to multiple arrangements.

d. Time-shared multiple terminals are available where management, production and engineering can concurrently design, edit, plot, and make changes with no system degradation.

e. Software packages are flexible and expandable to fit every need.

f. Libraries of standard drawing entries can be produced on the final drawing by simple pushbutton entries - section nomenclature, transistor figures, standard symbols, etc.

g. Most importantly, within a few weeks users can be trained to operate the system for simple designs such as usually constitute the bulk of the work.

The research in the area of CAD shows quite conclusively that this technology is being rapidly acquired by large companies whose product lines require continual generation of new designs. Even smaller organizations are having success with a move to CAD. Expectations are rising with the usually cheaper, certainly more powerful, computer and software changes. Developments are: (1) to turnkey CAD/CAM systems with a mini-computer-based drafting/designing feature and with a stand-alone capability, and (2) to large-scale engineering systems run by remote terminals from the large main frame computer with the ability to support design drafting and heavy computations.

There is no question that computers will continue to become increasingly more of a part of the manufacturing process of operation. There is a natural hesitancy to introduce new technology such as CAD unless its cost-effectiveness is immediate and crystal clear. However, where early installations of low cost minimal starter CAD systems were made extensive expansions rapidly followed. The benefits of CAD soon became familiar to all and the problems of user education acceptance easily resolved.

## 6. ECONOMICS.

Are the changes in manufacturing production methods justified in terms of the accrued economic benefits commonly expressed as Return On Investment (ROI)? This is the answer most sought and important to any operation. The advantages of CAM, CAD and GT are usually reported or published in general terms, such as a certain percentage reduction in production time or work in process. While these factors do affect manufacturing costs, it is imperative to determine their effects on the ROI.

The search for case histories showing validated cost savings for these technologies reveals that such data are almost nonexistent. Costs and related data of this nature are often considered to be highly proprietary, making such information almost impossible to obtain. Conversely, the substantiation of the cost savings derived using NC machine tools where the proper work-mix between NC and conventional machine tools has been determined is well documented. Even so, the use of NC machines is still limited to a small percent of the total manufacturers in this country.

What then is the answer to getting data on economics? The cost saving indicators, such as design and drafting time reductions, shorter turn-around times, etc., are so strong that cost reduction is to be expected. Concerted effort of large manufacturing companies in implementing total CAD/CAM systems is in itself an affirmation of their cost effectiveness.

Abstracts from a hypothetical study found in literature, somewhat parallel in parts to this study, illustrate the potential economic benefits of the successful application of CAD/CAM systems. A comparison was made between conventional manufacturing techniques and the others using the new technologies of CAD/CAM, with both producing the same output. Based on four major categories, capital costs, reproduction costs, operating costs and material costs, a reduction of about 40% could be achieved.

A visit to the Otis Manufacturing Company, Carrollton, TX, by members of the NC/CAM Study Group, was made to learn of the implementation of group technology (MICLASS) to their manufacture of oil well equipments. Nearly all of their manufacturing problems were due to the queuing requirements of machine parts. Though no concrete figures were given, management has expectations that GT will definitely improve their ROI. It is usually estimated that it takes about three years to establish ROI figures for any new major manufacturing procedure. Even though their installation of GT is fairly recent, their early cost reduction predictions are highly significant.

The reasons for expecting a successful cost reduction using MICLASS are instructive and worth noting. First, the system has been devised by people with extensive practical machine shop experience. Their system designers know what actually happens on the shop floor and do not rely on academic theory. Second, computers are used to digest and analyze data quickly. With the MICLASS coding system, the computer can find similarities in operations and design. The resulting grouping of parts into families reduces the waiting time and setup time, resulting in potential savings of as much as 25%. In addition to reducing throughput times and increasing the efficiency of machine tool use, MICLASS leads to obvious other savings, such as machine tool purchases, work-in-process inventory and finished parts inventory.

The benefits of the MICLASS system accrue with time. Design retrieval benefits have been immediate, whereas other benefits are expected to take six to twelve months. The end results predicted are remarkable increases in efficiency and significant savings.

Statements have been made that the next industrial revolution will be based upon CAD/CAM. It has already started. Every prediction states

that savings ranging from 10 to 40% in the manufacture of parts are possible. Clearly, such savings can only lead to an increase on ROI.

#### 7. INVENTORY HIGHLIGHTS.

The Army inventory of industrial plant equipments (IPE) consists of 113,332 items with an acquisition cost of 1.325 billion dollars, and applies only to six types of IPE; metal cutting, welding, metal forming, heat treating and furnaces, electrical testing and measuring, and mechanical testing and measuring equipment. These data are contained in a 1978 vintage study of Army IPE by the US Army Industrial Base Engineering Activity, Rhode Island.

Of particular significance is the number of NC machines of this IPE inventory for the following metal working classes: boring, drilling, lathes, milling, machine centers, punching, grinding and forging. The Army inventory is shown in Fig. H-4. This figure was modified to show the NC machines existing in DESCOM at the present time as shown by Fig. H-3.

The Army NC Machine Inventory consists of 360 items with an acquisition cost of approximately 54 million dollars and represents a significant contribution to the production capacity.

Figure H-4 shows some important facts. These are: (1) The 31 NC units in DESCOM are about 9 percent of the total in DARCOM. (2) The NC machines in DESCOM are all active as compared with DESCOM with 89 percent active and 11 percent inactive (5 percent intermittent use, 6 percent in plant equipment packages).

What is important from these facts is that DESCOM has been slow in acquiring necessary NC machines, that their NC machines are all active and that the percentage of NC machines in DESCOM is low compared with the total in DARCOM.

The need for NC machines in DESCOM is expected to increase much more rapidly since the complexity of parts is increasing due to the advanced technology being applied to Army equipments and to corresponding maintenance requirements by DESCOM (radars, solid-state units, optical systems, etc.), thus making NC machines essential and more cost effective.

The history of NC machines in DESCOM shows that their introduction and application has met with inertia and funding obstacles even though the requests were made along with justifiable cost analyses.

From the slow acquisition and introduction of NC machines into the depot, it clearly indicates that the advances of NC technology have not

been fully exploited in improving depot operations. By staying with conventional machines, depot parts manufacturing is lock-stepped to old-fashioned established procedures, some of which are outmoded. The work-mix analysis clearly points to the need of more NC machines for the depots and the retirement of conventional types.

The facts clearly show that the application of NC is not progressing fast enough in DESCOM to promote and further a necessary mode of operation. Without added impetus, this technology shows no promise of becoming a major cost effective production influence in its biggest area of potential application -- small- and middle-sized machining operations.

## **8. ROBOTICS.**

Robotics is a new NC/CAM technology that is blossoming with many possibilities and applications that are too numerous to cover herein; consequently, only those pertinent to the study are reviewed.

Robot development for industrial applications appeared around 1960. This was due to major advances in computer technology and the surge of computer applications. However, industrial-type robots experienced limited applications until around 1975.

There are several thousand industrial robots in use in the United States, covering a wide range of assemblies, configurations and capabilities from simple parts placement or removal of devices to computer programmed point-to-point or continuous-path operating units. These many new applications were developed and based upon the expectation of substantial financial rewards. The ensuing increase in the number of robots is partially due to the 200-300% increase in labor costs over the past 10 years as compared to only a 50% increase in robot costs; however, their increase in use is primarily due to their versatility, capability, reliability, and cost-effectiveness. Where the applications have been carefully selected and analyzed on a return-on-investment basis, the robots have proven to be highly cost-effective.

A robot design is a failure, however, unless it is adaptable to a broad range of jobs. This promotes large series production which is necessary to reduce the heavy R&D costs.

One of the biggest growth areas in industry today for industrial robots is that of automatic machine loading. This is true for all types of machine equipments, whether a transfer machine, an NC machine tool, or a conventional machine.

The growth pattern is one of increased use and the trend is upward. Applications are expected to increase dramatically as robot capabilities

are continually improved through the continuing rapid advances in computer technology. Robots are being developed that are capable of making decisions. By including electronic imaging devices, the robot essentially has been given eyes. The imaging device tied to a computer provides a powerful tool which has been given a degree of artificial intelligence for making simple decisions.

The range of applications and future developments possible with robots is intriguing and challenges companies to look for new uses; however, prospective users need to carefully evaluate each application for cost-effectiveness since maintenance costs are known to be exceptionally high.

a. Types and Applications. The introduction of the industrial robots for use in all of DESCOM requires a review of the various types and their potential applications. The application of industrial robots in DESCOM is quite limited. So far, it has only been applied to the disarming of ammunition at AEO, Tooele.

Industrial robots usually consist of several major components; manipulators, controllers, and power sources. Robot configurations function in a number of coordinate systems: rectangular, cylindrical, spherical or a combination thereof. The robot systems are nonservo or servo-control and need to be interfaced with other equipments and computers. The servo-control class of robots are further separated into point-to-point and continuous-path devices.

The nonservo robots are referred to as end-point, bang-bang, pick-and-place, or limited sequence. The manipulator members of nonservo robots move until the stops are reached, and there are usually two positions per axis. A sequencer provides for the many motions in a program. The sequence program can be modified by integrated sensors such as imagers, accelerometers, etc. These robots are fairly high-speed with good repeatability (within 0.01 in.). In addition, their cost is relatively low; they are simple to program and operate; the maintenance is low; and the reliability is high.

Servo-controlled robots have major advantages: (1) the manipulator members move anywhere within the limits of their travel, (2) velocity and acceleration can be controlled, (3) continuous and point-to-point travels are possible, and (4) accuracy can be varied by adjusting the feedback. Smooth motions are characteristic of servo systems and positioning and accuracy repeatability are 0.06 in. Servo-controlled robots, because of their complexity, are more expensive and tend to be less reliable.

Another major area deals with interfacing the robot. The robot must receive early information on the operation it is to perform. After executing the operation, the robot must feed back information to the controller or computer to start a new cycle. Each robot application usually generates a new interfacing problem. The user is soon educated to the fact that a robot is a cross between a computer and a form of action arm tied to the machine.

The highly developed robots of today are a blessing to man since he does not now work directly with toxic materials or on hot, demoralizing and dangerous jobs.

In a survey of applications of industrial robots one fact is clear, they will continue to fill hazardous jobs which are dangerous to human health or contain unacceptable working conditions. Spraying, plating, sand blasting, and similar operations fall into the health hazard category and become prime candidates for robotics. Manually fed presses and cutting tools, the handling of explosives and toxic materials, and the control of radioactive substances all fall into this category. The consensus of the NC/CAM Study Group is that industrial robots in this category could be utilized by DESCOM for the following: ammunition de-milling, painting, plating, shop peening, and sand blasting. These high-hazard and toxic gaseous fume areas are excellent candidates for robotics. Furthermore, it was learned by an NC Study Group attendee of the Automated Process Control, Monitoring and Industrial Robots Conference, February 1979, Ogden, Utah, that such applications are highly economic with a 50-60% reduction in manhours.

Other jobs robots can do are numbered in expected order of importance for DESCOM:

(1) Machine Tool Operation: Load, unload, part transfer, palletizing, machine center assistance, etc.

(2) Material Transfer: Maintenance assembly, inventory, palletizing, loading/unloading, etc.

(3) Welding: Automatic spot, press, and arc welding.

(4) Stamping Presses: Automatic load/unload, and parts transfer.

Every operation in a depot is a candidate for robotics as separate from automation or mechanization.

#### **b. Observations.**

There are a number of valid arguments for DESCOM to pursue the application of robotics:

- a. There is a need for minimizing hazardous jobs.
- b. With the rising cost of labor, robots become correspondingly more economical.
- c. Most of the technology for developing robotics now exists in NC/CAD/CAM.
- d. Robots are tireless and are not tied to a time clock.

One pitfall in the use of robotics is a requirement for scarce, highly-skilled, and expensive maintenance personnel.

For those companies successfully using industrial robotics, their advice is not to be afraid to use them. With our background in NC/CAM, it is a simple step to install and operate a robot for a specific application on a profitable basis. There is a strong compulsion of humans to use humans for industry. This inhibition must be overcome before robotics will come into its own. The time is here to study further applications of robotics for DESCOM, and a decision to do so should not be biased by conjecture.

#### 9. SUMMARY AND CONCLUSIONS.

There are numerous examples of successful applications of CAM in industry and a relatively few for the Army. These were reviewed for this study. The structures of companies and their manufacturing policies and purposes differ considerably from those of the individual depots in DESCOM. Therefore, there were not many one-to-one correspondences in applications and especially in operations in CAM for companies as compared to the depots. Consequently, to clearly identify those CAM applications in industry, and certainly in all the Services, which would benefit DESCOM, research and evaluation studies such as for this NC/CAM Report is required and certainly recommended.

The special derivatives of CAM such as Group Technology (GT) and CAM-I, Automated Process Planning (CAPP), etc., are just a part of CAM and must be individually reviewed to identify their applications for DESCOM.

Also, a survey is necessary of the various types of computers presently in operation at all depots, their applications and utilization. What are the computer needs and programs of the depots currently, and in the future, as they relate to CAM? Unless CAM applications are known to management, progress to utilize their benefits will take a long time.



Out of the study of CAD, two strong recommendations can be unequivocally made: (1) for any depot with no CAD capability, a starter system, even minimal, would be invaluable in readying a depot for capitalizing on the benefits of present day computer technology and its increased benefits predicted for the future, and (2) depots already having a CAD capability should conduct a survey to determine how to expand CAD to other activities such as are already experiencing success in industry.

The economics of NC, CAM, and CAD cannot be assessed overnight and will require a compilation of data from all the depots on a systematic basis. How such data can be gathered, analyzed, tabulated and distributed has no simple answer. The work-mix computer program is a step in the right direction and needs to be expanded to include CAD and CAM.

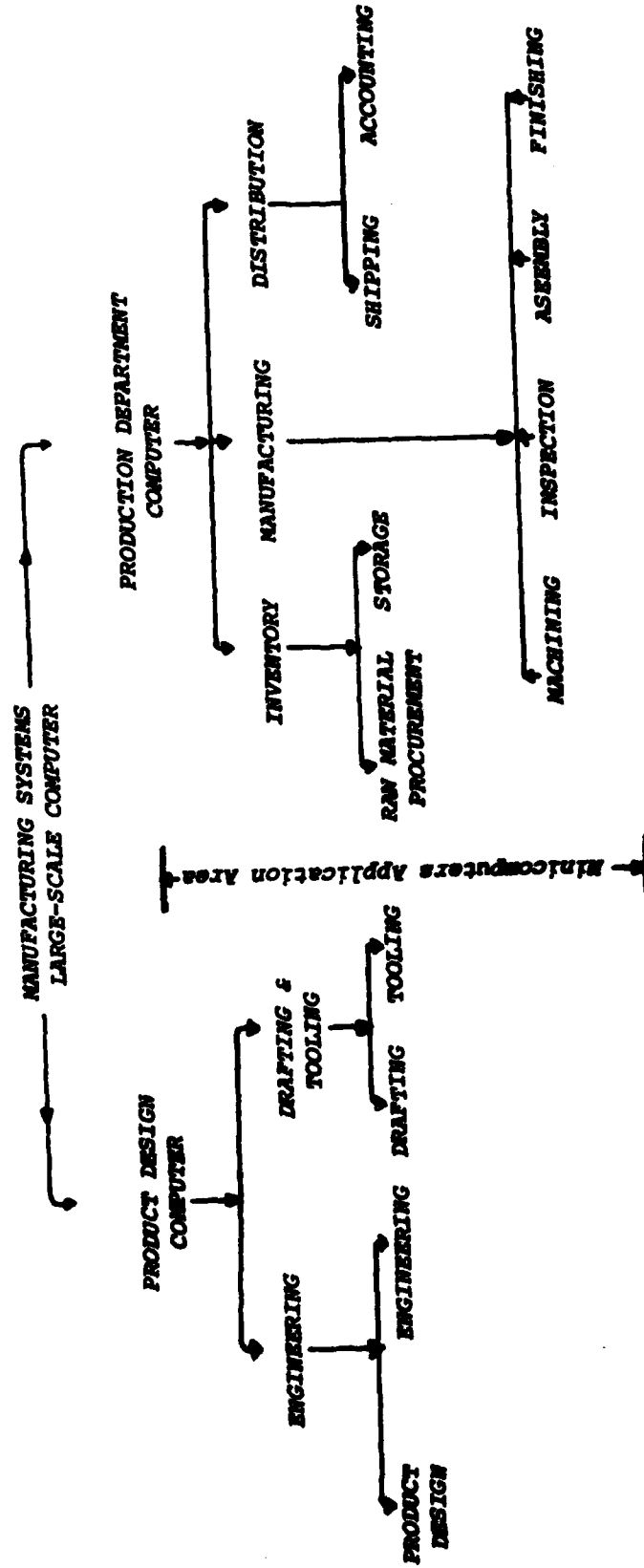


Fig. H-1. Total CAM system concept for possible depot application using hierarchical large-scale computer

Fig. H-2.

## DESCON Present &amp; Projected NC &amp; Conventional Machine Tool Requirements

## Part 1

Depot	Present Inventory				FY79				FY80			
	NC Machine		Conventional		NC Machine		Conventional		NC Machine		Conventional	
	Qty	\$	Qty	\$	Qty	\$	Qty	\$	Qty	\$	Qty	\$
Anniston (ANAD)	3	412	1,145	19,828	2	402	37	1,341	3	363	45	943
Corpus Christi (CCAD)	9	726	309	4,998	2	90	22	365	5	472	11	465
Letterkenny (LEAD)	-	-	67	2,387	-	-	-	-	4	741	3	175
Mainz (MZAD)	3	424	64	1,245	-	-	6	1,186	2	600	2	443
New Cumberland (NCAD)	-	-	62	915	-	-	8	135	-	-	4	39
Pueblo (PADA)	0	0	12	193	-	-	-	-	-	-	-	-
Red River (RRAD)	-	-	195	3,392	1	165	6	834	5	1,396	7	489
Sacramento (SAAD)	3	271	70	822	-	-	-	-	5	860	3	38
Seneca (SEAD)	-	-	-	-	-	-	-	-	-	-	-	-
Sharpe (SHAD)	-	-	-	-	-	-	-	-	-	-	-	-
Sierra (SIAD)	-	-	12	126	-	-	-	-	-	-	-	-
Tobyhanna (TOAD)	6	391	200	3,669	-	-	8	435	4	911	30	613
Tooele (TEAD)	5	1,036	138	1,931	2	520	14	271	3	665	13	263
Savanna (SADA)	2	162	71	661	-	-	-	-	1	150	-	-
Amo Eqpmt Ofc (Tooele)	-	-	21	-	-	-	3	83	-	-	1	23
DESCON Total	31	3,422	2,366	40,167	7	1,177	104	4,650	32	6,158	119	3,491

Fig. H-2 (cont'd).

## DESCON Present &amp; Projected NC &amp; Conventional Machine Tool Requirements

## Part 2

Depot	FY81				FY82				FY83			
	NC Machine		Conventional		NC Machine		Conventional		NC Machine		Conventional	
	Qty	\$	Qty	\$	Qty	\$	Qty	\$	Qty	\$	Qty	\$
Anniston (ANAD)	-	-	33	737	-	-	35	889	0	-	29	797
Corpus Christi (CCAD)	-	-	13	450	-	-	30	840	-	-	23	825
Letterkenny (LEAD)	-	-	-	-	-	-	2	200	-	-	1	25
Mainz (MZAD)	2	500	-	-	-	-	-	-	-	-	-	-
New Cumberland (NCAD)	-	-	6	114	-	-	3	84	-	-	8	106
Pueblo (PADAD)	-	-	-	-	-	-	-	-	-	-	-	-
Red River (RRAD)	-	-	5	225	-	-	6	343	-	-	5	213
Sacramento (SARD)	1	45	-	-	-	-	3	133	-	-	1	30
Seneca (SEAD)	-	-	-	-	-	-	-	-	-	-	-	-
Sharpe (SHAD)	-	-	-	-	-	-	-	-	-	-	-	-
Sierra (SIAD)	-	-	-	-	-	-	-	-	-	-	-	-
Tobyhanna (TOAD)	-	-	23	352	-	-	-	-	-	-	4	43
Tooele (TEAD)	-	-	9	210	-	-	22	366	-	-	26	467
Savanna (SADA)	-	-	-	-	-	-	-	-	-	-	-	-
Amo Eqpt Ofc (Tooele)	-	-	1	45	-	-	1	37	-	-	-	-
DESCON Total	3	545	90	2,133	-	-	102	2,892	-	-	97	2,506

Fig. H-2 (cont'd).

DESCON Present & Projected NC & Conventional Machine Tool Requirements

Part 3

Depot	*Totals (End of FY83)			
	NC Machine		Conventional	
	Qty	\$	Qty	\$
Anniston (ANAD)	5		400 12 less	
Corpus Christi (CCAD)	15		297 12 less	
Letterkenny (LEAD)	5**		106**	
Mainz (MZAD)	7			
New Cumberland (NCAD)	2 (1985-86)		42 4 less	
Pueblo (PADA)	-		-	
Red River (RRAD)	9		183 12 less	
Sacramento (SAAD)	8			
Seneca (SEAD)	-		-	
Sharpe (SHAD)	0		-	
Sierra (SIAD)	0		-	
Tobyhanna (TOAD)	11		195 5 less	
Tooele (TEAD)	14		125 13 less	
Savanna (SADA)				
Ammo Eqpmt Ofc-Tooele				
DESCON Total	76		1348	

\* These columns represent the projected total of NC machines and the remaining conventional machines. A newly purchased NC machine may have replaced one or more conventional machines; thus the total conventional machines can show a reduction.

\*\*Only in the Sheet Metal & Machine Shop, Directorate for Maintenance.

Fig. H-3.

TYPES OF NC MACHINES IN PRESENT DESCON INVENTORY

	MACHINES									
	Boring	Drilling	Lathes	Milling	Machine Center	Punching	Grinding	Forging	EDM	Total
<b>Depots</b>										
Anniston (ANAD)			2			1				3
Corpus Christi (CCAD)		1	4	2		1	1			9
Letterkenny (LEAD)										0
Mainz (MZAD)		1	1		1					3
New Cumberland (NCAD)										0
Pueblo (PADA)										0
Red River (RRAD)										0
Sacramento (SAAD)		1			1	1				3
Seneca (SEAD)										0
Sharpe (SHAD)										0
Sierra (SIAD)										0
Tobyhanna (TOAD)		1			3	1	1			6
Tooele (TEAD)		2		1	1	1				5
Savanna (SADA)	1			1						2
Ammo Eqpmnt Ofc (Tooele)										0
<b>DESCON TOTAL</b>	<b>1</b>	<b>6</b>	<b>7</b>	<b>4</b>	<b>6</b>	<b>5</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>31</b>

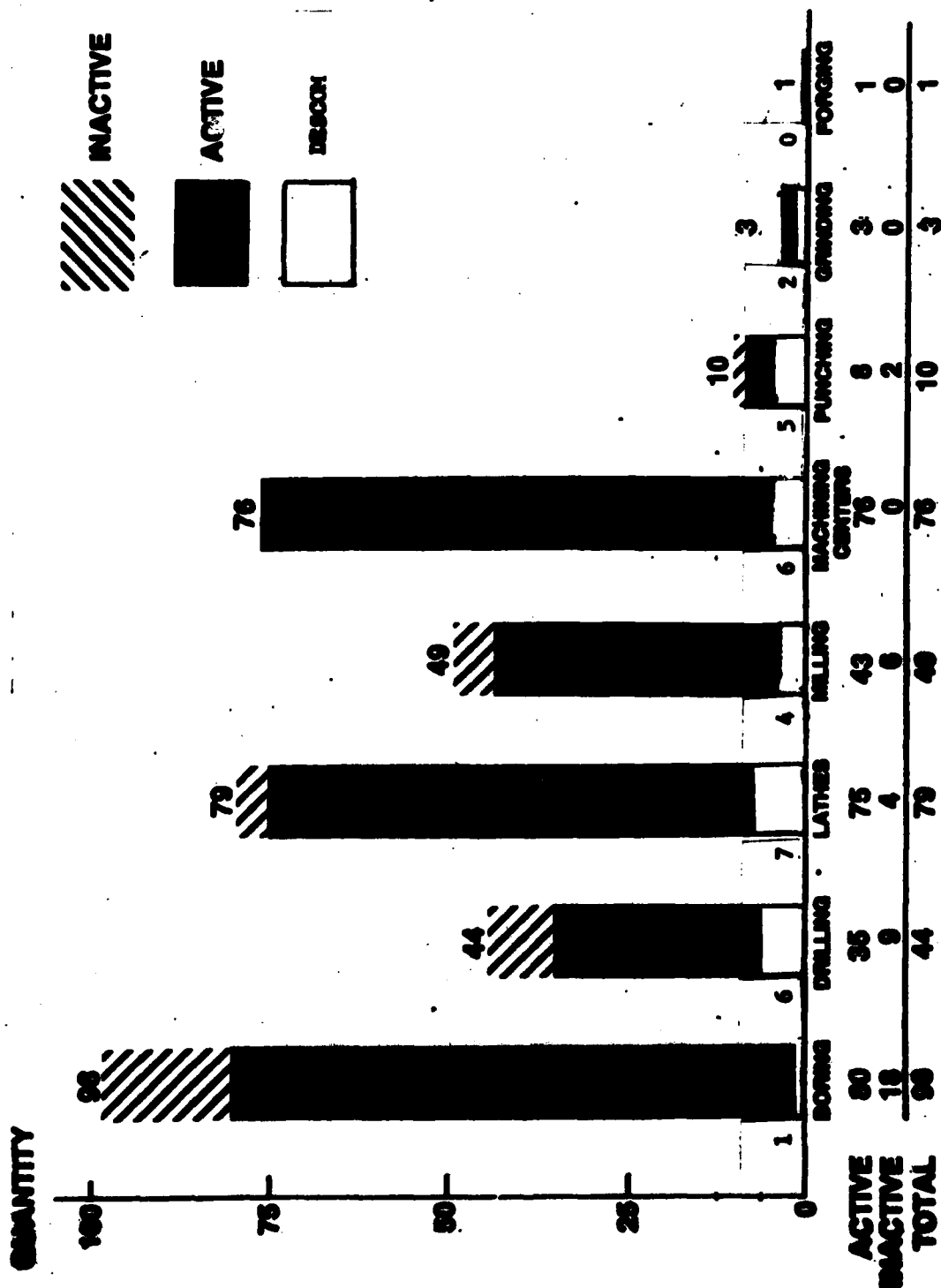


Fig. H-4. Comparison of inventories of NC machines by class between DARCOM and DESCOM.

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